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by

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DIGITAL COMPUTER SOLUTIONS OF AMIDSHIP STRUCTURAL DESIGN PROBLEMS

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ABSTRACT

This thesis describes the programming of amidship structural design procedures for the IBM-704 computer.

Two problems, the selection of scantlings and plating for the amidships portion of a ship's hull and the design of a transverse web frame are programmed for a digital computer. A detailed explanation of the programs and a brief discussion of the methods of approach for adapting these design procedures to a digital computer are included.

Using rather simple engineering criteria, these programs essentially carry out the design procedures for the amidship's structure. The inputs are those forces, moments, dimensions and material characteristics which are either known or can be readily determined by the user. The information resulting from these programs is given in a convenient form. The programs have been written in such a manner that they may be easily followed and altered.

It is strongly emphasized that these programs are written with a factor of safety of 1.0 on the yield strength of the material. By suitably selecting the input information, any reasonable factor of safety may be obtained.

Conclusions:

a. The results of experiments regarding structural components can be readily incorporated into programs such as those contained in this thesis.

b. Digital computers can be used to solve extremely complex structural problems.

c. In general, the limitations imposed by the computer on a problem are less restrictive than those imposed by manual methods.

Recommendations:

a. The second program, that for the design of a transverse web frame is not working in all respects. The difficulties involved with this program are described in the main body of the thesis. These problems must be solved before this program can be considered useful.

b. The programs in this thesis should be expanded to include the best engineering knowledge and theory available.

c. Investigations should be made to adapt this approach to designing a grillage network similar to that of ref. 8.

Thesis Supervisor: J. Harvey Evans
Title: Associate Professor of Naval Architecture

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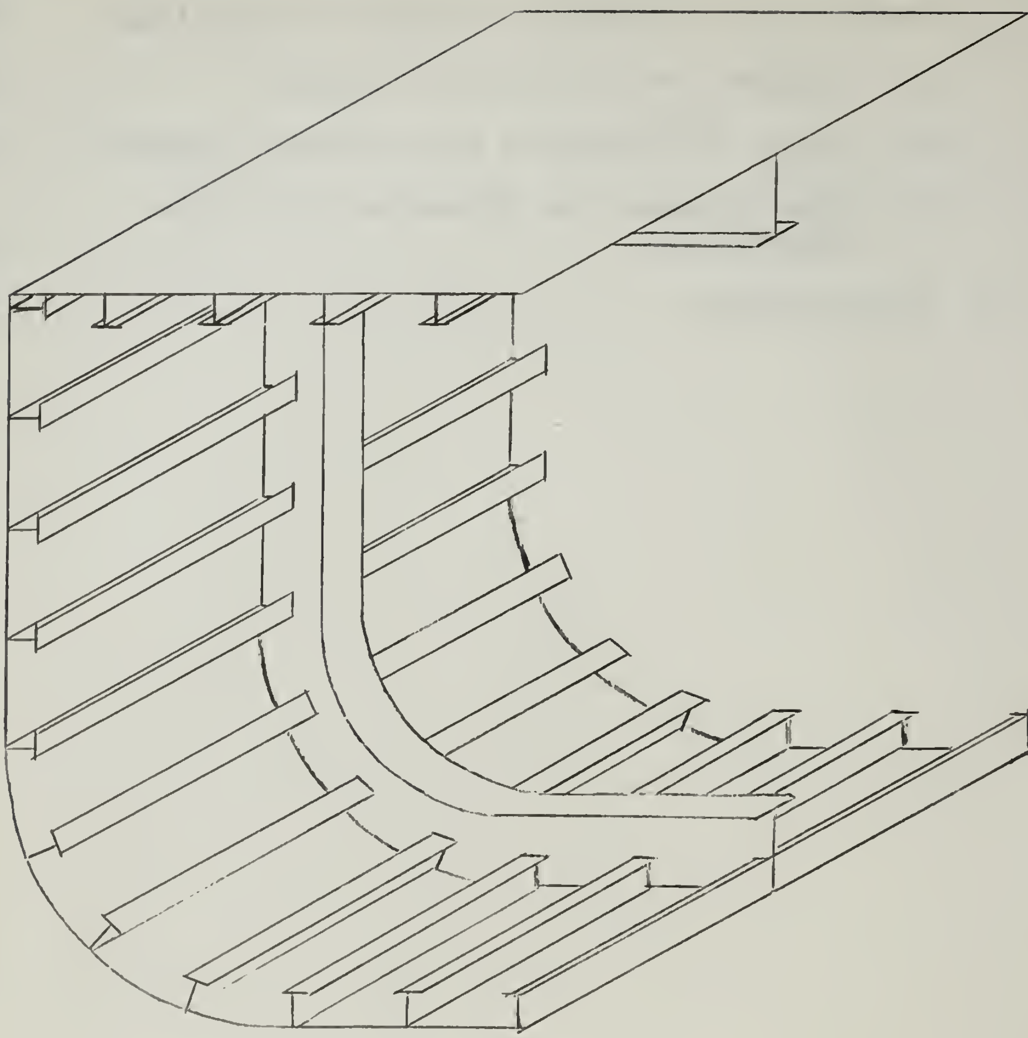


FIGURE 1

View of Structural Components of a Destroyer Type Hull

I. INTRODUCTION

The purpose of this work is to write computer programs which will select component members for a destroyer type hull such as that shown in Figure 1. This investigation has been divided into three parts, the first two of which are incorporated into this thesis:

(1) Write a computer program which will select scantlings and plating for an amidship's section of prescribed dimensions under the influence of bending moments and hydrostatic forces.

(2) Write a computer program which will size the web frame for the amidships section under the influence of internal and external forces.

(3) Review and analyze available engineering criteria and change the above programs in order that the design calculations may be carried out as accurately as possible.

In writing this thesis, knowledge of programming for the IBM 704 digital computer is assumed on the part of the reader. Selected parts of Ref. 1 are considered required reading before delving into the details of the programs included in this thesis. Part B of the Procedure and Part 1 of Appendix A are included only as aids and are not in themselves a complete review of programming procedures.

Several philosophies have prevailed throughout the writing of these programs. Foremost, the simplicity of the program routines is such that users may readily understand

the processes being carried out. Since these programs essentially form the bases for more precise programs of this nature, the computations are broken up into relatively short steps to facilitate the alteration of criteria used in the program. The criteria used in these programs are of necessity quite elementary. This restriction was one of the author's, not of the computer. An effort has been made to maintain a factor of safety of 1.0 throughout the program within the bounds of the criteria used. This was done since a uniformly strong structure is considered to be most desirable.

The program for selecting scantlings has been written for optimizing the amidships design within ranges of web frame spacing and numbers of equally spaced longitudinals. The program for computing the dimensions of the transverse web frame follows prescribed rules for designing built up beams. The web thickness is kept constant and other dimensions are varied. Both programs operate on the stress schedule approach of design.

The program for sizing the transverse web frame requires that the number of longitudinals and frame spacing be specified and remain constant throughout the program. This is due to the limitations involved in introducing ship's weights into the problem.

Admittedly there are shortcomings to be found in these programs. These programs are believed to be the first of this type, and it is felt that a considerable amount of improvement is both possible and probably quite desirable.

It is emphasized that the answers, which these programs produce, are not in themselves conclusive. These answers do require a fair amount of evaluation. However, the idea of condensing several days of manual calculations into as many minutes of machine calculations makes this project a very worthwhile endeavor indeed.

II. PROCEDURE

PART A

PREPARATION OF SCANTLING DATA

The data which describes the shape of the scantlings was obtained directly from the AISC Manual (1957) for "T" sections and was computed from the information tabulated in ref. 2 in the case of "I-T" sections. This latter information was calculated by hand but has not been completely verified for accuracy.

The following terminology pertains to the conversion of data for I-T beam-plate sections to that of I-T beam sections:

A_2 area of stiffener-plate combination

A_3 area of stiffener alone

c'_3 distance of neutral axis from the flange of the stiffener alone

d depth of stiffener

I_2 moment of inertia of stiffener-plate combination

I_3 moment of inertia of the stiffener alone

t plate thickness

YF distance of neutral axis from the flange of the stiffener-plate combination

YP distance of neutral axis from the plate of the stiffener-plate combination

λ effective width of plating

Calculations were made from tabulated values for which: $\lambda = 60$, $t = 1"$

$$A_2 = A_3 + \lambda t^2 = A_3 + 60$$

$$YF - c_3' = \frac{\lambda t^2}{A_2}(d - c_3' + \frac{t}{2}) = \frac{A_2 - A_3}{A_2}(YF + YP - c_3' - \frac{t}{2})$$

$$(YF - c_3')(1 - \frac{A_2 - A_3}{A_2}) = \frac{A_2 - A_3}{A_2}(YP - t/2)$$

$$(YF - c_3')(\frac{A_3}{A_2}) = (\frac{A_2 - A_3}{A_2})(YP - t/2)$$

$$(YF - c_3') = \frac{\lambda t}{A_3}(YP - \frac{t}{2}) = \frac{1}{A_3}(60YP - 30)$$

$$c_3' = YF - \frac{1}{A_3}(60YP - 30)$$

$$I_2 = I_3 + A_3(YF - c_3')^2 + \frac{\lambda t^4}{12} + \lambda t^2(YP - \frac{t}{2})^2$$

$$I_3 = I_2 - A_3(YF - c_3')^2 - \frac{\lambda t^4}{12} - \lambda t^2(YP - \frac{t}{2})^2$$

$$I_3 = I_2 - A_3(YF - c_3')^2 - 5 - 60YP^2 + 60YP - 15$$

$$I_3 = I_2 - (60YP - 30)^2 - 60YP^2 + (60YP - 30) + 10$$

The values of I_{3yy} for I-T sections were assumed to be approximately one half that of the uncut I sections.

The scantlings are stored in order of increasing cross sectional areas. For each scantling, the following order of data is used: USN designation, A_3(area), c_3' (dist. of neutral axis from flange), I_3 (moment of inertia about neutral axis), I_{3yy}(moment of inertia about axis of symmetry), o, o, d (depth).

PART B

PROGRAMMING NOTES

The following subroutines are employed by the programs in this thesis:

Subroutine	Mnemonic Code	SHARE Designation	SHARE Distribution list	SYN
Square Root	SQRT	MISRT1	399	/356
Sine	SIN	UAS⌿C1	013	/423
Cosine	COS	UAS⌿C1	013	/424
Generalized Print	BLOCK	UABDC1	72	/520
Write on Tape	WOT	UASTH1	72	/1376
Post Mortem	PMR	MICMD1	NON-SHARE	/121

The SYN octal number designations refer to frequently used subroutines currently listed under PAK at the Computation Center at M.I.T. (ref. 7a).

These programs were written in accordance with SHARE Assembly procedures and are available in both mnemonic and absolute binary form at the Department of Naval Architecture and Marine Engineering at M.I.T. Moreover, these programs were written as an Automatic Operator Program (ref. 7b). The administrative instructions at the beginning and end of these programs pertain specifically to the above.

The programs are each broken up into three parts: Data, Program and Input. The parts have been set up through administrative instructions so that the first two parts may be read into the IBM 704 computer in absolute binary form, and the Input information may be read in in the more convenient decimal form to be subsequently assembled with the other two parts. The print out format is under program control.

All lists of information which are tagged to an index register in the program are terminated by a set of -1.0's. Thus, for each list of data or intermediate information, a positive end of the list escape is provided. If an escape occurs in the data listings, i.e., all plate thicknesses or all scantlings did not meet the criteria for a station, indication of such an escape is recorded for subsequent post mortem information. However, most of the loops use this means for their termination during the normal course of computations.

A block of registers starting with LOC are used to store intermediate and final values resulting from the calculations. LOC is the station number for scantling or plate centerline. LOC+1 and LOC+2 are the z and y coordinates respectively for the station. The two stations beyond the last pertinent one are given the coordinates of (-1.0, -1.0). The loops which are repetitive for each or every other station are terminated by transferring on a negative coordinate. Since all other coordinates are positive, this procedure provides an effective means for terminating many repetitive calculations.

Indexing instructions (TXI) are written without a decrement part. The decrements are placed in these instructions at the beginning of the program. By altering only two or three numbers, the whole program can be altered with respect to size to conform to changing criteria. Care should be taken to insure that all instructions within the program with LOC as an address conform to this change.

Negative numbers are used in the decrements. Indexing instructions are specified by a five character alphabetic code: IND$\alpha\beta$. α stands for all such instructions having the same decrement value. β provides the identification for the particular indexing instruction. Examples: INDAA, INDBS, etc.

Non indexing instructions are specified by a five character alphabetic code: INS$\alpha\beta$. $\alpha\beta$ identifies the particular instruction. For the most part, these instructions are in alphabetic sequence starting with INSAA, INSAB, etc. Exceptions to this rule have resulted from the many modifications which these programs have undergone. The designation "*" refers to "this address" with respect to instructions.

These programs operate in the floating trap mode and provision has been made for setting the accumulator to zero and returning to the main program when an underflow ($AC < 10^{-38}$) occurs. Of course, an overflow ($AC > 10^{+38}$) will stop the program. Few escapes have been written for error returns from subroutines. It has been felt desirable to stop the program wherever such an event occurs.

The post mortem dump includes the information listed under LOC. It is here that nearly all of the intermediate information is stored, and searching for errors should commence in this area if the input cards have been found to be correct. Normally there is no need for the post mortem dump and the PMD, PMR and XPM cards are removed.

PART C

Input and Output Formats for Selection of Plating and Scantlings

1. The following conventions apply to the input format:

   a. The order of reading in and assembling input data is to be the same as that listed below. The units to be used are indicated on the input listing.

   b. Since floating point instructions are used, all numbers comprising the input data must have decimal points inserted.

   c. If the SAP deck is to be assembled for the first time, precede the input program with "CST M885-721-PROGRAM" and use "INPUT" as the address of the ORG card. The octal address of INPUT is used when combining the INPUT program with the absolute binary decks of the DATA and PROGRAM parts.

   Input Format with sample problem inserted:

```
REM INPUT INFORMATION FOR PROGRAM M885
SAP M885-721-INPUT
LST OFF
ORG (the octal address of INPUT)
DEC 30.0            (FT)  DEPTH
DEC 35.0            (FT)  BEAM
DEC 17.0            (FT)  BILGE RADIUS
DEC 11.7            (FT)  FULL LOAD DRAFT
DEC 18.7            (FT)  WAVE CREST HEIGHT ABOVE KEEL
DEC 84.0            (IN)  INITIAL FRAME SPACING
DEC 10.0            (IN)  INCREMENT OF FRAME SPACING
```

```
DEC 84.0            (IN)  FINAL FRAME SPACING
DEC 52.0                  INITIAL NUMBER OF LONGITUDINALS
DEC 10.0                  INCREMENT OF NUMBER OF LONGITUDINALS
DEC 52.0                  FINAL NUMBER OF LONGITUDINALS
DEC 0.05                  ACCURACY CRITERION FOR MOM. OF INERT.
DEC 12540.0   (FT-TONS)   BENDING MOMENT, SAGGING
DEC 28100.0   (FT-TONS)   BENDING MOMENT, HOGGING
DEC 4.0             (FT)  MINIMUM HYDROSTATIC HEAD
DEC 60000.0        (PSI)  ULTIMATE STRENGTH
DEC 33000.0        (PSI)  YIELD STRENGTH IN TENSION
DEC 33000.0        (PSI)  YIELD STRENGTH IN COMPRESSION
DEC 30000000.0     (PSI)  YOUNG'S MODULUS
DEC 2000.0         (PSI)  SECONDARY BENDING STRESS AT PLATE
END 0
```

2. Printout Format with answers for sample problem inserted:

   Note: The program has been altered since Appendix C was typed. Intermediate values of locations of neutral axes are printed out concurrently with intermediate values of moments of inertia.

```
RUN M885-721-PROGRAM
REM AMIDSHIP DESIGN PROBLEM
REM THIS REQUIRES THE SELECTION OF PLATING AND SCANTLINGS
REM FOR A DESIGNATED HULL SHAPE UNDER THE INFLUENCE
REM OF PRESCRIBED FORCES AND MOMENTS
BIN M885-721-DATA-DAVIS*00
BIN M885-721-PROGRAM*00
BIN M885-721-INPUT*00
PMD M885-721-PROGRAM
```

CLR

PAK

RIP M885-721-DATA-DAVIS

RIP M885-721-PROGRAM

RIP M885-721-INPUT

BGN M885-721-PROGRAM

The foregoing information are the administrative instructions pertaining to the program. Next, the intermediate values of moments of inertia (in^4) and locations of neutral axes (in) were printed out. In this case nineteen tries were made before all accuracy criteria were met.

Several comments are in order concerning the print out format. Floating point notation is used in some instances. Two examples are the best illustration of floating point numbers: 0.503E02 = 50.3, 0.607E-01 = 0.0607. The number following the letter E is the power of 10 by which the number preceding the letter E is to be multiplied. Area is given in square inches. A is the web frame spacing in inches, and N is the total number of equally spaced longitudinals. Moments of Inertia are given in units $in.^2 ft.^2$ Inertia pl refers to the moment of inertia for the ship in the sagging condition and similarly inertia min. for the hogging condition. Locations are numbered consecutively as shown in Figure 3 in Appendix C. Z and y distances are measured in inches from the keel along the centerline and base line respectively. Scantlings are indicated by their USN designation with the exception that "I" refers to "I-T" sections. Plate thicknesses are indicated in lbs/square foot.

INERTIA PL= 0.35123213E 05   INERTIA MIN= 0.41415150E 05
NEUTRAL AXIS SAG= 159.3 NEUTRAL AXIS HOG= 199.1

AREA= 0.27954086E 03   N= 62.0   A= 84.0

INERTIA PL= 0.3543546E 05   INERTIA MIN= 0.40221344E 05

LOCATION= 0.0 Z= 0.0 Y= 0.0

10.0X4.00X 11.51
LENGTH/RADIUS OF GYRATION= 30.0

LOCATION= 1.0 Z= 0.1 Y= 13.0 WT= 20.4

LOCATION= 2.0 Z= 1.0 Y= 26.6

10.0X4.000X 11.51
LENGTH/RADIUS OF GYRATION= 30.0

LOCATION= 3.0 Z= 2.8 Y= 40.0 WT= 17.8

LOCATION= 4.0 Z= 5.5 Y= 52.8

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 30.0

LOCATION= 5.0 Z= 8.9 Y= 66.0 WT= 17.8

LOCATION= 6.0 Z= 13.2 Y= 78.3

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 30.0

LOCATION= 7.0 Z= 18.4 Y= 91.0 WT= 17.8

LOCATION= 8.0 Z= 24.3 Y= 102.5

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.9

LOCATION= 9.0 Z= 31.0 Y= 114.0 WT= 15.3

LOCATION= 10.0 Z= 38.4 Y= 125.1

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.9

LOCATION= 11.0 Z= 46.5 Y= 136.0 WT= 15.3

LOCATION= 12.0 Z= 55.3 Y= 145.6

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.8

LOCATION= 13.0 Z= 64.7 Y= 155.0 WT= 14.0

LOCATION= 14.0 Z= 74.7 Y= 163.8

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.8

LOCATION= 15.0 Z= 85.3 Y= 172.0 WT= 12.7

LOCATION= 16.0 Z= 96.4 Y= 179.3

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.7

LOCATION= 17.0 Z= 107.9 Y= 186.0 WT= 11.5

LOCATION= 18.0 Z= 119.8 Y= 191.8

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.7

LOCATION= 19.0 Z= 132.1 Y= 197.0 WT= 10.2

LOCATION= 20.0 Z= 144.7 Y= 201.2

8.0X2.250X 6.501
LENGTH/RADIUS OF GYRATION= 29.6

LOCATION= 21.0 Z= 157.6 Y= 205.0 WT= 7.6

LOCATION= 22.0 Z= 170.7 Y= 207.3

8.0X2.250X 6.501
LENGTH/RADIUS OF GYRATION= 29.5

LOCATION= 23.0 Z= 183.9 Y= 209.0 WT= 6.4

LOCATION= 24.0 Z= 197.1 Y= 209.9

8.0X2.250X 6.501
LENGTH/RADIUS OF GYRATION= 29.5

LOCATION= 25.0 Z= 210.5 Y= 210.0 WT= 6.4

LOCATION= 26.0 Z= 223.8 Y= 210.0

8.0X2.250X 6.501
LENGTH/RADIUS OF GYRATION= 29.4

LOCATION= 27.0 Z= 237.1 Y= 210.0 WT= 7.6

LOCATION= 28.0 Z= 250.4 Y= 210.0

8.0X2.250X 6.501
LENGTH/RADIUS OF GYRATION= 29.3

LOCATION= 29.0 Z= 263.7 Y= 210.0 WT= 8.9

LOCATION= 30.0 Z= 277.0 Y= 210.0

8.0X2.250X 6.501
LENGTH/RADIUS OF GYRATION= 29.2

LOCATION= 31.0 Z= 290.4 Y= 210.0 WT= 10.2

LOCATION= 32.0 Z= 303.7 Y= 210.0

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.2

LOCATION= 33.0 Z= 317.0 Y= 210.0 WT= 11.5

LOCATION= 34.0 Z= 330.3 Y= 210.0

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.1

LOCATION= 35.0 Z= 343.6 Y= 210.0 WT= 12.7

LOCATION= 36.0 Z= 356.9 Y= 210.0

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.0

LOCATION= 37.0 Z= 360.0 Y= 200.0 WT= 12.7

LOCATION= 38.0 Z= 360.0 Y= 186.4

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.0

LOCATION= 39.0 Z= 360.0 Y= 173.0 WT= 12.7

LOCATION= 40.0 Z= 360.0 Y= 159.8

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.0

LOCATION= 41.0 Z= 360.0 Y= 146.0 WT= 12.7

LOCATION= 42.0 Z= 360.0 Y= 133.2

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.0

LOCATION= 43.0 Z= 360.0 Y= 120.0 WT= 12.7

LOCATION= 44.0 Z= 360.0 Y= 106.5

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.0

```
LOCATION= 45.0  Z=  360.0  Y=  93.0  WT= 12.7

LOCATION= 46.0  Z=  360.0  Y=  79.9

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION=  29.0

LOCATION= 47.0  Z=  360.0  Y=  67.0  WT= 12.7

LOCATION= 48.0  Z=  360.0  Y=  53.3

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION=  29.0

LOCATION= 49.0  Z=  360.0  Y=  40.0  WT= 12.7

LOCATION= 50.0  Z=  360.0  Y=  26.6

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION=  29.0

LOCATION= 51.0  Z=  360.0  Y=  13.0  WT= 12.7

LOCATION= 52.0  Z=  360.0  Y=   0.0

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION=  29.0

LOCATION= 53.0  Z=  -1.0   Y=  -1.0

TER M885-721-PROGRAM
```

PART D

Input and Output Formats for Sizing the Transverse Web Frame

1. The Input Format is the same as that for Part C just preceding with the following exceptions:

   a. Initial and final values for each of the following must be equal: number of longitudinals and frame spacing. Note: some value greater than zero must be inserted for increments of numbers of longitudinal and increments of frame spacing.

   b. Insert the following information immediately before "END 0" in the INPUT program described in Part C:

```
ORG (octal address of LOAD)
DEC 700., 500., 200., 200., 0., 0., 0., 0., 0.
DEC 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.
DEC 100., 100., 100., 100., 100., 100., 100., 100.,
DEC 100., 100.
```

   The LOAD data pertains to the weights (in lbs.) applied at the intersections of scantlings and the web frame by machinery, etc., within the ship. The first value under LOAD refers to the weight applied at the keel. Successive values refer to weights applied at successive even numbered stations. It is for this reason that the number of equally spaced longitudinals must be specified and remain fixed. The preceding format permits stacking of data on relatively few cards. Note that decimal points must be inserted.

The same convention applies to the ORG cards used in part C as well as that of the preceding format. In the latter case "LOAD" is the title of the ORG card when "INPUT" is so used in the preceding case. The CST instruction of part C covers both LOAD and INPUT data in this case.

The output format indicates the dimensions of the web frame. All dimensions are in inches.

Intermediate values of the redundant force and moment are printed out. These values are indicated in the Results and Discussion. The format which follows is given in addition to the printout format of the previous subsection.

```
LOCATION=   0.0    Z=   0.0    Y=   0.0
TW=      .  TF=      .  D=      .  W=      .
LOCATION=   2.0    Z=   1.0    Y=  26.6
TW=      .  TF=      .  D=      .  W=      .
LOCATION=   4.0    Z=   5.5    Y=  52.8
TW=      .  TF=      .  D=      .  W=      .
LOCATION=   6.0    Z=  13.2    Y=  78.3
TW=      .  TF=      .  D=      .  W=      .
LOCATION=   8.0    Z=  24.3    Y= 102.5
TW=      .  TF=      .  D=      .  W=      .
LOCATION=  10.0    Z=  38.4    Y= 125.1
TW=      .  TF=      .  D=      .  W=      .
LOCATION=  12.0    Z=  55.3    Y= 145.6
TW=      .  TF=      .  D=      .  W=      .
LOCATION=  14.0    Z=  74.7    Y= 163.8
TW=      .  TF=      .  D=      .  W=      .
LOCATION=  16.0    Z=  96.4    Y= 179.3
```

TW= . TF= . D= . W= .

LOCATION= 18.0 Z= 119.8 Y= 191.8

TW= . TF= . D= . W= .

LOCATION= 20.0 Z= 144.7 Y= 201.2

TW= . TF= . D= . W= .

LOCATION= 22.0 Z= 170.7 Y= 207.3

TW= . TF= . D= . W= .

LOCATION= 24.0 Z= 197.1 Y= 209.9

TW= . TF= . D= . W= .

LOCATION= 26.0 Z= 223.8 Y= 210.0

TW= . TF= . D= . W= .

LOCATION= 28.0 Z= 250.4 Y= 210.0

TW= . TF= . D= . W= .

LOCATION= 30.0 Z= 277.0 Y= 210.0

TW= . TF= . D= . W= .

LOCATION= 32.0 Z= 303.7 Y= 210.0

TW= . TF= . D= . W= .

LOCATION= 34.0 Z= 330.3 Y= 210.0

TW= . TF= . D= . W= .

LOCATION= 36.0 Z= 356.9 Y= 210.0

TW= . TF= . D= . W= .

LOCATION= 38.0 Z= 360.0 Y= 186.4

TW= . TF= . D= . W= .

LOCATION= 40.0 Z= 360.0 Y= 159.8

TW= . TF= . D= . W= .

LOCATION= 42.0 Z= 360.0 Y= 133.2

TW= . TF= . D= . W= .

LOCATION= 44.0 Z= 360.0 Y= 106.5

TW=	.	TF=	.	D=	.	W=	.
LOCATION=	46.0	Z=	360.0	Y=	79.9		
TW=	.	TF=	.	D=	.	W=	.
LOCATION=	48.0	Z=	360.0	Y=	53.3		
TW=	.	TF=	.	D=	.	W=	.
LOCATION=	50.0	Z=	360.0	Y=	26.6		
TW=	.	TF=	.	D=	.	W=	.
LOCATION=	52.0	Z=	360.0	Y=	0.0		
TW=	.	TF=	.	D=	.	W=	.

III. RESULTS

The numerical results obtained from the computer solutions of the first program are contained in subsection C-2 under Procedure.

The first program has been run and is known to be correct. This program selects longitudinals and plating for a ship's hull. This program has been completely verified by hand calculations. The input and output formats are designed for convenience and are contained in section C of the Procedure.

The second program, that of sizing the transverse web frame, has been written but it is not working. The part of this program up through page 129 is known to be correct. The part of this program written on pages 130 through 138 are believed to be correct, but bear checking. It is felt that the difficulty lies somewhere in pages 139 through 152.

Both programs have the following limitations:

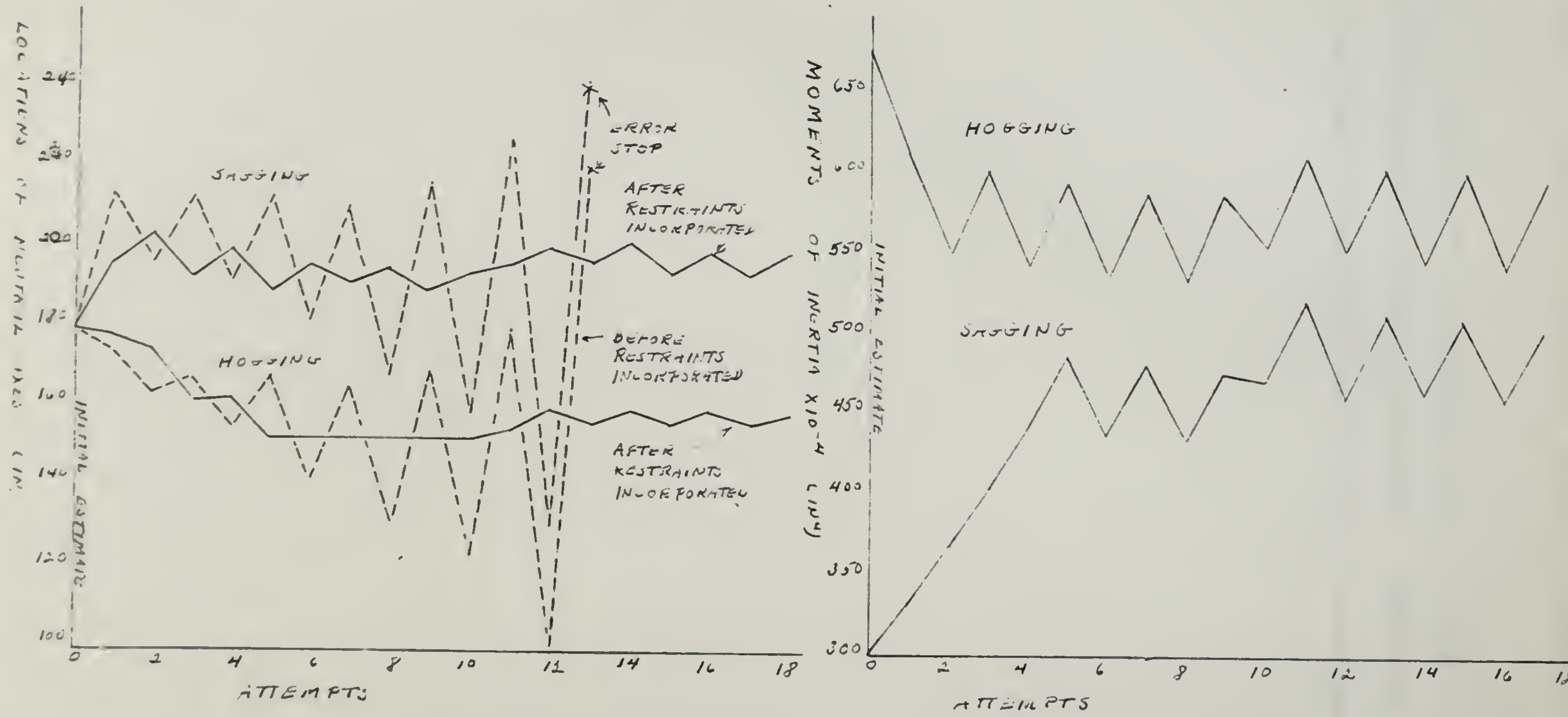
1. The frame scantlings are evenly spaced and are placed symmetrically about the ship centerline.
2. The points defining the hull section are symmetrical about the ship centerline.
3. One of these points is on the centerline keel.
4. The hull shape is defined by its beam, depth, and bilge radius.

The web frame program has the following additional limitations (aside from the fact that it is not working):

1. Symmetrical loading with respect to the centerline.
2. No stanchions are used.

3. No account is taken of shear strains or shear stresses.

Computer time for calculation of scantlings and plating was around 5 minutes. Computer time for calculation of the web frame dimensions might be as much as 20 minutes.



PLOT OF INTERMEDIATE VALUES OF LOCATIONS OF NEUTRAL AXES
AND OF MOMENTS OF INERTIA

IV. DISCUSSION OF RESULTS

The aims of this thesis as originally specified were not fully met. As originally planned, the program for selecting scantlings and plating was to have been used to generate curves indicating optimum numbers of longitudinals and frame spacings for different hull geometries under bending and hydrostatic loads. This aim was not met due to a critical shortage of computer time available. Moreover, most of the available computer time was utilized in the debugging phases. However, this program was written to select the optimum (least weight) combination of number of longitudinals and frame spacing and to print out the data for this combination.

One of the more important points to note is the fact that these programs are written for a factor of safety of 1.0 on the specified yield stress. In both programs, stress schedules provide the fundamental criterion for selecting components of the hull structure. In all cases stresses are assumed to be uniaxial. The sum of stresses resulting from different loadings are never permitted to exceed the specified yield stresses.

The graphs on the opposite page are included to point out the area which deserves immediate attention for the sake of improving these programs. The use of four related values z_c^+, z_c^-, I_1^+ and I_1^- makes this program inherently unstable. Accordingly, moments of inertia are varied by a percentage amount (10%) until computed and assumed values

[illegible]

agree to within a specified amount. In this case the accuracy criterion was five percent. As is indicated in these graphs, the use of computed values of locations of neutral axes as the new assumed values led to an unstable solution. This difficulty was rectified by using the mean of assumed and computed values of locations of neutral axes as the new assumed values.

The process of making new estimates of moments of inertia is still considered to be unsatisfactory since too many attempts must be made to arrive at a solution.

The transverse web frame program did not run to a solution. This program was run for 10 minutes during which time two values each of redundant moment and redundant force were obtained. It appears as though the difficulty might be associated with the flow diagram for this program rather than to any specific instruction. There was insufficient computer and calendar time available to pursue this matter further.

Perhaps one of the more important parts of this investigation is the use of a logical approach to the amidship's hull design. The computer is a relatively stupid beast and has no capability other than to obey instructions at an incredibly fast rate. Neither esthetic values nor the successes of previous designs can be used unless they are somehow incorporated into the specific criteria within the program.

The criteria used in these programs are usually quite simple. The main purpose here is to at least provide a

(Note: there is no Page 25)

logical position in the programs for more exact criteria. In a sense, these programs are frameworks for future developments of this nature. It is emphasized that the simplicity of the criteria used was not caused by the computer but rather by the calendar time available to the author.

It is felt that with a suitably sized shoe horn these programs can be written for the IBM-650 computer. This computer has 4000 memory addresses as compared with the 32786 core locations plus magnetic drums and tapes available for the IBM-704 computers. This comparison should provide an indication of how much these programs can be expanded if the IBM-704 computer or its successors are to be used.

A considerable portion of time spent on this project was devoted to debugging the programs. An appreciation of this fact can be gained by noting that every letter, number, comma and period must be correct. The programs were written in such a manner as to make debugging a relatively easy process. Nevertheless, this was the most frustrating and discouraging part of this investigation.

These programs are as well documented as could be done within a reasonable number of pages. Again it should be pointed out that some of the criteria bears checking and refining. It is hoped that users will find this thesis as valuable to them in their work as it has been to the author in preparing it.

V. CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions:

The results of experiments regarding structural components can be readily incorporated into programs such as those contained in this thesis. The results must be in some mathematical form but can be as complex as is desired to reflect actual observed conditions.

Digital computers can be used to solve extremely complex structural problems. Ref. 8 contains an example of such a structural problem. Here, a grillage framework for a destroyer type hull is analyzed. This analysis is nearly impossible to carry out by hand within a reasonable amount of time. It is felt that an era of extensive hand calculations for the analysis and design of complex structures is rapidly coming to an end. The high degree of engineering required for efficient structures, of the complexity of a ship's hull for instance, require the use of high speed computers for design and analysis processes.

In general, the limitations imposed by the computer on a problem are less restrictive than those imposed by manual methods. Two observations bear this fact out. First, the computer can be used to solve complex differential equations which may arise from proven theory almost as efficiently as it can the normal algebraic expressions often encountered in design work. Secondly, computer programs can be expanded to encompass a wide range of engineering knowledge to be applied in the design processes accomplished by the particular programs.

Accordingly, much more efficient use can be made of the most precise theories available. It would be remiss not to point out the fact that the designer's time can be much more effectively used to evaluate the results of designs calculated by the computer rather than doing the calculations manually.

2. <u>Recommendations</u>:

The programs in this thesis should be expanded to include the best engineering knowledge and theory available. As has been pointed out in the discussion of results, the criteria used in these programs are quite basic. There is a considerable amount of room for improvement in this field.

Once the above has been carried out to a reasonable extent, investigations should be made to adapt this approach to designing a grillage network similar to that of Ref. 8. Once this has been done, it is felt that the programs will be quite valuable indeed in designing hull structures for the destroyer type ships. In addition, these programs could be adapted to other types of hulls and an effort should be made in that direction.

VI. APPENDICES

APPENDIX A

GLOSSARY

1. List of Frequently Used Computer Instructions

Explanations accompanying the following operation codes are not necessarily technically correct. However, they are deemed sufficient for readers who have had little or no experience in programming for the IBM-704 Data Processing System.

CLA Y	Clear the accumulator (AC), (Set to 0) and add the contents of address Y.
FAD Y	Add (floating point) the contents of Y to the contents of the accumulator.
STO Y	Store the contents of the (AC) in the address Y.
LDQ Y	Load the multiplier quotient register (MQ) with the contents of Y.
STQ Y	Store the contents of the (MQ) in the address Y.
LDQ X FMP Y STO Z	A series of instructions in which the contents of X are multiplied by the contents of Y and the result thereof is stored in the address Z.
CLA X FDP Y STQ Z	A series of instructions in which the contents of X are divided by the contents of Y and the quotient thereof is stored in the address Z.
CAS Y	Compare the contents of the (AC) with those of the address Y: If the c(AC) > c(Y), go to the next instruction. If the c(AC) = c(Y), skip one instruction. If the c(AC) < c(Y), skip two instructions.
NOP	No operation, go to the next instruction.
HTR	Error stop
HLT	End of program
REM	Remark, this operation code has no significance other than that of information.
CHS	Change the algebraic sign of the contents of (AC).
SSP	Set the algebraic sign of the contents of (AC) plus.
SSM	Set the algebraic sign of the contents of (AC) minus.
TRA Y	Absolute transfer of control to the instruction having the address Y.

TMI Y	Transfer to Y if the contents of the (AC) are negative.
TLQ Y	Transfer to Y if the contents of the (AC) are greater than the contents of the (MQ).
TSX ---,4	Exit for a subroutine.
LXD NIX,K	Used to set the contents of index register(s) K to zero.
TXI Y,K,N	Transfer control to Y and increment the contents of index register(s) K by the amount N. In this and the previous instruction the value of K affects the following registers:

K	: 1,	2,	3,	4,	5,	6,	7.
Index Registers:	1,	2,	1&2,	4,	2&3,	2&4,	1&2&4.

The TXI instruction changes the effective addresses of all instructions tagged to index register K. In these programs, negative numbers are used for N. For example:

```
LOC,1   = LOC      when index register 1 =   0
LOC,2   = LOC+50     "     "       "    2 = -50
LOC+5,1 = LOC+75     "     "       "    1 = -70
```

2. Index of Notation:

The following symbols and definitions are those commonly used in this thesis. Inconsistencies in their usage are explained where they occur.

A Area

A_1^+ Total effective area of ship's hull in the sagging condition.

A_1^- Total effective area of ship's hull in the hogging condition.

A_2 Total area of a beam-plate combination.

A_2^- Effective area of a beam-plate combination in compression.

a Frame spacing.

a_o Initial frame spacing.

Δa Increment of frame spacing.

a_f Final frame spacing.

B Beam.

b Longitudinal spacing.

b_o Initial longitudinal spacing.

c Location of neutral axis of beam or beam-plate combination.

c_2 Distance of neutral axis from extreme plate fibre of total area of beam-plate combination.

c_2^- Distance of neutral axis from extreme plate fibre of effective area of beam-plate combination in compression.

c_2' Distance of neutral axis from extreme flange fibre of total area of beam-plate combination.

$c_2'^-$ Distance of neutral axis from extreme flange fibre of effective area of beam-plate combination in compression.

c_3' Distance of neutral axis from extreme flange fibre of total area of beam alone.

c-w Vertical load on transverse web frame.

D Depth of ship's hull, width of web plating.

d Depth of beam.

E Young's Modulus.

F Full load draft.

H Head of salt water.

H_o Minimum head of salt water.

H_ω Head of salt water due to ship in the hogging condition.
H_θ Head of salt water due to ship inclined to a specified angle of heel.

I Moment of inertia.
I_1^+ Effective moment of inertia of the ship hull in the sagging condition.
I_1^- Effective moment of inertia of the ship hull in the hogging condition.
ΔI Specified accuracy criterion for moment of inertia and redundant forces and moments.
I_2 Effective moment of inertia of the beam-plate combination under lateral load.
I_2^- Effective moment of inertia of the beam-plate combination under end compressive load.
I_{2yy} Total moment of inertia of the beam-plate combination about the y-y axis. (axis of symmetry)
I_{2yy}^- Effective moment of inertia of the beam-plate combination about the y-y axis under end compression load.
I_3 Moment of inertia of the beam alone about its x-x axis.
I_{3yy} Moment of inertia of the beam alone about its axis of symmetry.

k Radius of gyration.

M Bending moment.

M_o Redundant bending moment.
M_{ex} Moment due to external loads.
M_1^+ Ship (primary) bending moment in the sagging condition.
M_1^- Ship (primary) bending moment in the hogging condition.
M_2 Secondary bending moment due to lateral load on the beam-plate combination.

n Number of longitudinals.

n_o Initial number of longitudinals.
Δn Increment of number of longitudinals.
n_f Final number of longitudinals.

P Axial force.
P_o Redundant axial force
P_{ex} Axial force due to external loads.

Q First moment of area, shear force.

R Bilge radius.

S Shear force.

t Plate thickness.

t_f Flange thickness.
t_w Web thickness.

V Total vertical shear force.

W	Wave crest height above keel, ship in hogging condition.
y	Coordinate direction perpendicular to centerline plane of ship's hull.
z	Coordinate direction in the centerline plane and perpendicular to the base line in the fore and aft direction.
z_c^+	Distance from the base line to the neutral axis of the hull in the sagging condition.
z_c^-	Distance from the base line to the neutral axis of the hull in the hogging condition.
σ	Stress intensity.
σ_{A}	Axial stress.
σ_{ULT}	Ultimate strength.
σ_{YP}^+	Yield strength in tension.
σ_{YP}^-	Yield strength in compression.
σ_1^+	Primary stress (tension) due to bending of ship hull.
σ_1^-	Primary stress (compression) due to bending of ship hull.
σ_2	Secondary stress due to lateral load on beam-plate combination.
σ_3	Tertiary stress due to lateral load on plating.
λ	Effective breadth of plating under lateral load.
λ^-	Effective width of plating under end compression.
θ	Angle.
$\Delta\theta$	Increment of angle.

APPENDIX B

PLATE AND SCANTLING DATA

```
RUN M885-721-PROGRAM
REM AMIDSHIP DESIGN PROBLEM
REM THIS REQUIRES THE SELECTION OF PLATING AND SCANTLINGS
REM FOR A DESIGNATED HULL SHAPE UNDER THE INFLUENCE
REM OF PRESCRIBED FORCES AND MOMENTS.
SAP M885-721-DATA-DAVIS
LST NONE
PRG OFF
ORG /70000
```

```
      REM PLATE DATA, IN ORDER OF INCREASING THICKNESSES,
      REM WT PER SQUARE FOOT, THICKNESS, IN INCHES, THICKNESS
      REM SQUARED IN THAT ORDER
PLATE DEC 5.10,0.125,0.015625,6.37,0.1562,0.024414,7.65,0.1875,0.035156
      DEC 8.92,0.2187,0.047830,10.20,0.2500,0.0625,11.47,0.2812
      DEC 0.079073,12.75,0.3125,0.097656,14.02,0.3437,0.118130,15.30
      DEC 0.3750,0.140625,17.85,0.4375,0.191406,20.40,0.5000,0.250000
      DEC 22.95,0.5625,0.316406,25.50,0.6250,0.390625,28.05,0.6875
      DEC 0.472656,30.60,0.7500,0.562500,35.70,0.8750,0.765625,40.80
      DEC 1.0000,1.000000,45.90,1.1250,1.265625,51.00,1.2500,1.562500
      DEC 61.20,1.5000,2.250000
      DEC -1.0,-1.0,-1.0
      REM SCANTLING DATA, U S N BEAM DESIGNATION, I
      REM REFERS TO I-T SECTIONS, DEC DATA, AREA, DIST OF
      REM NEUTRAL AXIS TO FLANGE, TWO MOMENTS OF INERTIA,
      REM TWO BLANKS, DEPTH, IN THAT ORDER
SCANT BCD 3  3.0X1.875X 2.20T
      DEC 0.65,0.84,0.58,0.082,0.,0.,3.00
      BCD 3  4.0X2.250X 3.25T
      DEC 0.96,1.18,1.59,0.17,0.,0.,4.00
      BCD 3  6.0X1.875X 4.40I
      DEC 0.99,2.19,4.71,0.09,0.,0.,6.00
      BCD 3  3.0X4.000X 4.25T
      DEC 1.25,0.64,0.90,0.94,0.,0.,2.92
      BCD 3  7.0X2.125X 5.50I
      DEC 1.25,2.60,7.70,0.13,0.,0.,7.00
      BCD 3  5.0X2.750X 4.50T
      DEC 1.32,1.53,3.46,0.30,0.,0.,5.00
      BCD 3  4.0X4.000X 5.00T
      DEC 1.48,0.96,2.15,1.00,0.,0.,3.95
      BCD 3  8.0X2.250X 6.50I
      DEC 1.53,2.87,9.00,0.17,0.,0.,8.00
      BCD 3  5.0X4.000X 5.75T
      DEC 1.69,1.35,4.15,1.00,0.,0.,4.94
      BCD 3  6.0X3.000X 5.90T
      DEC 1.72,1.88,6.59,0.49,0.,0.,6.00
      BCD 3  3.0X4.000X 6.00T
      DEC 1.77,0.67,1.30,1.44,0.,0.,3.00
      BCD 3  6.0X4.000X 8.50I
      DEC 1.77,1.78,7.12,0.95,0.,0.,5.83
      BCD 3  4.0X4.000X 6.50T
      DEC 1.91,1.03,2.90,1.31,0.,0.,4.00
      BCD 3  6.0X4.000X 7.00T
      DEC 2.07,1.76,7.70,1.13,0.,0.,5.96
      BCD 3 10.0X2.750X 9.00I
      DEC 2.17,3.91,24.48,0.31,0.,0.,10.00
      BCD 3  8.0X4.000X10.00I
      DEC 2.19,2.72,18.19,1.00,0.,0.,7.90
      BCD 3  5.0X4.000X 7.50T
      DEC 2.20,1.37,5.46,1.39,0.,0.,5.00
      BCD 3  4.0X4.000X 7.50T
      DEC 2.22,1.00,3.29,1.65,0.,0.,4.06
      BCD 3  3.0X4.000X 8.00T
      DEC 2.36,0.67,1.66,2.16,0.,0.,3.13
      BCD 3  6.0X4.000X 8.25T
      DEC 2.43,1.76,9.02,1.39,0.,0.,6.00
```

```
BCD 3  5.0X4.000X 8.50T
DEC 2.49,1.32,6.07,1.73,0.,0.,5.06
BCD 3  6.0X4.000X12.00T
DEC 2.49,1.97,13.49,1.45,0.,0.,6.00
BCD 3  4.0X4.000X 8.50T
DEC 2.50,0.84,3.21,3.36,0.,0.,4.00
BCD 3 10.0X4.000X 11.5I
DEC 2.63,3.45,26.12,1.01,0.,0.,9.87
BCD 3 12.0X3.000X 11.8I
DEC 2.75,4.52,42.53,0.49,0.,0.,12.00
BCD 3  5.0X4.000X  9.5T
DEC 2.80,1.28,6.70,2.09,0.,0.,5.13
BCD 3  6.0X4.000X  9.5T
DEC 2.81,1.67,10.2,1.84,0.,0.,6.08
BCD 3  8.0X4.000X 13.0I
DEC 2.88,2.82,23.62,1.31,0.,0.,8.06
BCD 3  4.0X5.250X 10.0T
DEC 2.94,0.83,3.66,4.25,0.,0.,4.07
BCD 3  5.0X5.750X 10.5T
DEC 3.10,1.06,6.31,4.87,0.,0.,4.95
BCD 3  6.0X4.000X 11.0T
DEC 3.24,1.63,11.7,2.27,0.,0.,6.16
BCD 3  6.0X4.000X 16.0I
DEC 3.26,1.89,16.02,2.16,0.,0.,6.25
BCD 3  8.0X4.000X 15.0I
DEC 3.27,2.62,22.00,1.65,0.,0.,8.12
BCD 3 12.0X4.000X 14.0I
DEC 3.30,4.54,56.83,1.13,0.,0.,11.91
BCD 3 10.0X4.000X 15.0I
DEC 3.40,3.60,39.55,1.40,0.,0.,10.00
BCD 3  8.0X5.250X 17.0I
DEC 3.48,2.30,23.27,3.4,0.,0.,8.00
BCD 3  5.0X5.750X 12.5T
DEC 3.67,1.02,7.12,6.34,0.,0.,5.04
BCD 3 10.0X4.000X 17.0I
DEC 3.77,3.52,45.07,1.73,0.,0.,10.12
BCD 3 12.0X4.000X 16.5I
DEC 3.86,4.56,66.59,1.40,0.,0.,12.00
BCD 3  6.0X6.500X 13.5T
DEC 3.98,1.21,11.4,8.30,0.,0.,5.98
BCD 3  8.0X5.250X 20.0I
DEC 4.03,2.28,28.14,4.30,0.,0.,8.14
BCD 3 10.0X4.000X 19.0I
DEC 4.18,3.37,45.92,2.10,0.,0.,10.25
BCD 3  5.0X5.750X 14.5T
DEC 4.27,1.05,8.38,7.61,0.,0.,5.11
BCD 3 12.0X4.000X 19.0I
DEC 4.34,4.36,70.84,1.85,0.,0.,12.16
BCD 3 10.0X5.750X 21.0I
DEC 4.35,2.86,42.33,4.90,0.,0.,9.90
BCD 3  7.0X6.750X 15.0T
DEC 4.41,1.59,19.0,8.77,0.,0.,6.93
BCD 3  6.0X6.500X 15.5T
DEC 4.56,1.22,13.0,9.90,0.,0.,6.04
BCD 3  8.0X6.500X 24.0I
DEC 4.63,2.00,30.86,9.10,0.,0.,7.93
```

```
BCD 3 12.0X4.000X 22.0I
DEC 4.94,4.26,81.09,2.28,0.,0.,12.31
BCD 3  7.0X6.750X 17.0T
DEC 5.00,1.55,21.1,10.6,0.,0.,7.00
BCD 3 10.0X5.750X 25.0I
DEC 5.06,2.87,56.75,6.4,0.,0.,10.08
BCD 3  6.0X6.500X 18.0T
DEC 5.29,1.26,15.3,11.9,0.,0.,6.12
BCD 3  8.0X7.000X 18.0T
DEC 5.40,1.90,30.7,11.1,0.,0.,7.93
BCD 3  8.0X6.500X 28.0I
DEC 5.42,2.04,34.90,10.8,0.,0.,8.06
BCD 3 12.0X6.500X 27.0I
DEC 5.53,3.44,84.58,8.3,0.,0.,11.95
BCD 3  7.0X6.750X 19.0T
DEC 5.59,1.56,23.50,12.3,0.,0.,7.06
BCD 3  8.0X7.000X 20.0T
DEC 5.88,1.82,33.20,13.3,0.,0.,8.00
BCD 3 10.0X5.750X 29.0I
DEC 5.88,2.88,63.17,7.6,0.,0.,10.22
BCD 3 12.0X6.500X 31.0I
DEC 6.30,3.43,99.63,9.9,0.,0.,12.09
BCD 3 14.0X6.750X 30.0I
DEC 6.38,4.37,137.99,8.8,0.,0.,13.86
BCD 3 10.0X8.000X 33.0I
DEC 6.45,2.51,63.90,18.3,0.,0.,9.75
BCD 3  8.0X7.000X 22.5T
DEC 6.62,1.87,37.8,15.2,0.,0.,8.06
BCD 3 14.0X6.750X 34.0I
DEC 7.15,4.26,151.08,10.7,0.,0.,14.00
BCD 3 12.0X6.500X 36.0I
DEC 7.34,3.57,125.17,11.9,0.,0.,12.24
BCD 3  8.0X7.000X 25.0T
DEC 7.35,1.89,42.2,17.4,0.,0.,8.13
BCD 3  9.0X7.500X 25.0T
DEC 7.35,2.14,53.9,18.6,0.,0.,9.00
BCD 3 10.0X8.000X 39.0I
DEC 7.54,2.47,72.29,22.5,0.,0.,9.94
BCD 3 16.0X7.000X 36.0I
DEC 7.78,5.10,213.49,11.1,0.,0.,15.85
BCD 3 12.0X8.000X 40.0I
DEC 7.91,3.17,121.08,22.1,0.,0.,11.94
BCD 3 14.0X6.750X 38.0I
DEC 7.96,4.29,172.97,12.3,0.,0.,14.12
BCD 3  9.0X7.500X 27.5T
DEC 8.09,2.16,59.6,21.0,0.,0.,9.06
BCD 3 16.0X7.000X 40.0I
DEC 8.50,5.06,250.63,13.3,0.,0.,16.00
BCD 3  8.0X8.500X 29.0T
DEC 8.52,1.70,43.6,30.2,0.,0.,7.93
BCD 3 10.0X8.000X 45.0I
DEC 8.66,2.53,88.43,26.6,0.,0.,10.12
BCD 3 14.0X8.000X 43.0I
DEC 8.70,3.84,178.37,22.6,0.,0.,13.68
BCD 3  9.0X7.500X 30.0T
DEC 8.82,2.17,64.8,23.5,0.,0.,9.12
```

```
BCD 3 12.0X8.000X 45.0I
DEC 8.94,3.31,146.87,25.0,0.,0.,12.06
BCD 3 10.5X8.250X 31.0T
DEC 9.12,2.59,93.7,26.6,0.,0.,10.49
BCD 3  8.0X8.500X 32.0T
DEC 9.40,1.73,48.3,34.2,0.,0.,8.00
BCD 3  9.0X8.750X 32.0T
DEC 9.40,1.93,61.8,35.2,0.,0.,8.94
BCD 3 16.0X7.000X 45.0I
DEC 9.59,5.08,274.69,15.3,0.,0.,16.12
BCD 3 14.0X8.000X 48.0I
DEC 9.70,3.88,202.08,25.7,0.,0.,13.81
BCD 3 12.0X8.000X 50.0I
DEC 9.94,3.32,159.32,23.2,0.,0.,12.19
BCD 3 10.5X8.250X 34.0T
DEC 10.01,2.59,102.8,30.2,0.,0.,10.57
BCD 3 12.0X10.00X 53.0I
DEC 10.16,2.96,151.29,48.1,0.,0.,12.06
BCD 3  9.0X8.750X 35.0T
DEC 10.28,1.96,68.1,39.2,0.,0.,9.00
BCD 3  8.0X8.500X 35.5T
DEC 10.43,1.77,54.0,38.9,0.,0.,8.08
BCD 3 16.0X7.000X 50.0I
DEC 10.65,5.13,310.26,17.4,0.,0.,16.25
BCD 3 14.0X8.000X 53.0I
DEC 10.72,3.95,229.16,28.8,0.,0.,13.94
BCD 3 10.5X8.250X 36.5T
DEC 10.73,2.60,110.2,33.1,0.,0.,10.62
BCD 3 18.0X7.500X 50.0I
DEC 10.76,5.81,392.61,18.6,0.,0.,18.00
BCD 3 12.0X10.00X 58.0I
DEC 11.05,2.97,170.50,53.7,0.,0.,12.19
BCD 3 12.0X9.000X 38.0T
DEC 11.18,3.00,151.1,38.3,0.,0.,11.95
BCD 3  9.0X8.750X 38.5T
DEC 11.32,1.99,75.3,44.3,0.,0.,9.08
BCD 3  8.0X8.500X 39.0T
DEC 11.46,1.81,60.0,43.8,0.,0.,8.16
BCD 3 18.0X7.500X 55.0I
DEC 11.84,5.82,428.16,21.0,0.,0.,18.12
BCD 3 14.0X10.00X 61.0I
DEC 11.92,3.60,242.90,53.7,0.,0.,13.91
BCD 3 16.0X8.500X 58.0I
DEC 12.00,4.72,328.74,30.3,0.,0.,15.86
BCD 3 10.5X9.000X 41.0T
DEC 12.05,2.48,115.4,44.8,0.,0.,10.43
BCD 3 12.0X9.000X 42.0T
DEC 12.35,2.97,165.9,44.2,0.,0.,12.04
BCD 3  9.0X8.750X 42.5T
DEC 12.49,2.05,84.4,49.7,0.,0.,9.16
BCD 3 18.0X7.500X 60.0I
DEC 12.87,5.89,486.69,23.6,0.,0.,18.25
BCD 3 16.0X8.500X 64.0I
DEC 13.23,4.77,386.35,34.2,0.,0.,16.00
BCD 3 18.0X8.750X 64.0I
DEC 13.29,5.35,465.46,35.2,0.,0.,17.87
```

```
BCD 3 14.0X10.00X 68.0I
DEC 13.31,3.75,270.34,60.6,0.,0.,14.06
BCD 3 21.0X8.250X 62.0I
DEC 13.54,6.98,677.75,26.6,0.,0.,20.99
BCD 3 12.0X9.000X 47.0T
DEC 13.81,2.99,185.9,51.1,0.,0.,12.15
BCD 3 13.5X10.00X 47.0T
DEC 13.83,3.41,238.5,57.5,0.,0.,13.45
BCD 3 9.0X11.75X 48.0T
DEC 14.11,1.78,85.3,103.4,0.,0.,9.08
BCD 3 10.5X9.000X 48.0T
DEC 14.11,2.55,137.1,54.7,0.,0.,10.57
BCD 3 14.0X10.00X 74.0I
DEC 14.49,3.73,307.14,66.8,0.,0.,14.19
BCD 3 18.0X8.750X 70.0I
DEC 14.55,5.43,519.91,39.3,0.,0.,18.00
BCD 3 16.0X8.500X 71.0I
DEC 14.70,4.87,423.58,39.0,0.,0.,16.16
BCD 3 12.0X12.00X 50.0T
DEC 14.71,2.54,176.7,101.8,0.,0.,12.00
BCD 3 21.0X8.250X 68.0I
DEC 14.82,6.98,746.75,30.2,0.,0.,21.13
BCD 3 14.0X12.00X 78.0I
DEC 14.84,3.36,286.32,103.5,0.,0.,14.06
BCD 3 13.5X10.00X 51.0T
DEC 15.01,3.39,257.7,64.8,0.,0.,13.53
BCD 3  9.0X11.75X 52.2T
DEC 15.43,1.82,93.9,115.5,0.,0.,9.16
BCD 3 21.0X8.250X 73.0I
DEC 15.87,7.02,809.99,33.1,0.,0.,21.24
BCD 3 15.0X10.50X 54.0T
DEC 15.88,4.03,349.5,67.6,0.,0.,14.91
BCD 3 14.0X12.00X 84.0I
DEC 15.96,3.40,315.49,112.8,0.,0.,14.18
BCD 3 18.0X8.750X 77.0I
DEC 16.02,5.52,590.62,44.3,0.,0.,18.16
BCD 3 16.0X8.500X 78.0I
DEC 16.17,4.95,476.16,43.8,0.,0.,16.32
BCD 3 12.0X12.00X 55.0T
DEC 16.18,2.57,195.2,114.5,0.,0.,12.08
BCD 3 10.5X13.00X 56.0T
DEC 16.47,2.06,136.4,144.8,0.,0.,10.50
BCD 3 24.0X9.000X 76.0I
DEC 16.71,8.03,1071.87,38.2,0.,0.,23.91
BCD 3  9.0X11.75X 57.0T
DEC 16.77,1.85,102.6,127.8,0.,0.,9.24
BCD 3 13.5X10.00X 57.0T
DEC 16.77,3.42,288.9,74.8,0.,0.,13.64
BCD 3 15.0X10.50X 58.0T
DEC 17.07,3.94,371.8,76.6,0.,0.,15.00
BCD 3 16.0X11.50X 88.0I
DEC 17.36,4.32,476.12,92.6,0.,0.,16.16
BCD 3 21.0X9.000X 82.0I
DEC 17.61,6.73,857.38,44.8,0.,0.,20.86
BCD 3 12.0X12.00X 60.0T
DEC 17.64,2.62,213.6,127.0,0.,0.,12.16
```

```
BCD 3 18.0X8.750X 85.0I
DEC 17.75,5.64,667.79,49.7,0.,0.,18.32
BCD 3 15.0X10.50X 62.0T
DEC 18.22,3.90,394.8,84.8,0.,0.,15.08
BCD 3 24.0X9.000X 84.0I
DEC 18.35,8.01,1205.39,44.2,0.,0.,24.09
BCD 3 10.5X13.00X 63.5T
DEC 18.67,2.11,155.8,169.3,0.,0.,10.62
BCD 3 16.0X11.50X 96.0I
DEC 18.89,4.33,518.23,103.6,0.,0.,16.32
BCD 3 12.0X14.00X 65.0T
DEC 19.11,2.47,222.6,187.6,0.,0.,12.13
BCD 3 16.5X11.50X 65.0T
DEC 19.13,4.37,513.0,100.7,0.,0.,16.55
BCD 3 18.0X11.75X 96.0I
DEC 19.15,4.98,672.75,103.4,0.,0.,18.16
BCD 3 15.0X10.50X 66.0T
DEC 19.41,3.90,420.7,92.5,0.,0.,15.15
BCD 3 24.0X9.000X 94.0I
DEC 20.49,8.05,1358.19,51.1,0.,0.,24.29
BCD 3 21.0X9.000X 96.0I
DEC 20.63,6.87,1036.48,54.7,0.,0.,21.14
BCD 3 24.0X12.00X100.0I
DEC 20.73,7.13,1323.64,101.8,0.,0.,24.00
BCD 3 27.0X10.00X 94.0I
DEC 20.75,9.11,1699.13,57.6,0.,0.,26.91
BCD 3 16.5X11.50X 70.5T
DEC 20.76,4.30,551.8,114.9,0.,0.,16.66
BCD 3 10.5X13.00X 71.0T
DEC 20.88,2.18,177.3,193.0,0.,0.,10.73
BCD 3 18.0X11.75X105.0I
DEC 20.95,5.03,741.09,115.5,0.,0.,18.32
BCD 3 12.0X14.00X 72.5T
DEC 21.31,2.48,246.2,217.1,0.,0.,12.24
BCD 3 13.5X14.00X 72.5T
DEC 21.34,2.85,316.3,203.5,0.,0.,13.44
BCD 3 18.0X12.00X 75.0T
DEC 22.08,4.79,696.7,125.2,0.,0.,17.92
BCD 3 16.5X11.50X 76.0T
DEC 22.35,4.26,591.9,128.1,0.,0.,16.75
BCD 3 27.0X10.00X102.0I
DEC 22.41,9.10,1864.14,64.8,0.,0.,27.07
BCD 3 21.0X13.00X112.0I
DEC 22.43,5.77,1091.41,144.9,0.,0.,21.00
BCD 3 18.0X11.75X114.0I
DEC 22.77,5.13,831.81,127.8,0.,0.,18.48
BCD 3 24.0X12.00X110.0I
DEC 22.80,7.19,1470.20,114.6,0.,0.,24.16
BCD 3 12.0X14.00X 80.0T
DEC 23.54,2.51,271.6,246.3,0.,0.,12.36
BCD 3 18.0X12.00X 80.0T
DEC 23.54,4.76,741.0,137.7,0.,0.,18.00
BCD 3 13.5X14.00X 80.0T
DEC 23.72,2.91,351.4,229.0,0.,0.,13.54
BCD 3 30.0X10.50X108.0I
DEC 24.38,10.52,2437.71,67.6,0.,0.,29.82
```

```
BCD 3 24.0X12.00X120.0I
DEC 24.91,7.28,1626.96,127.0,0.,0.,24.31
BCD 3 18.0X12.00X 85.0T
DEC 24.99,4.74,784.70,150.3,0.,0.,18.08
BCD 3 27.0X10.00X114.0I
DEC 25.01,9.15,2096.78,74.8,0.,0.,27.28
BCD 3 15.0X13.00X 86.0T
DEC 25.32,3.23,471.0,275.1,0.,0.,14.94
BCD 3 21.0X15.00X127.0I
DEC 25.45,5.89,1228.71,169.3,0.,0.,21.24
BCD 3 30.0X10.50X116.0I
DEC 25.93,10.39,2625.62,76.6,0.,0.,30.00
BCD 3 13.5X14.00X 88.5T
DEC 26.05,2.97,391.8,259.4,0.,0.,13.66
BCD 3 24.0X14.00X130.0I
DEC 26.42,6.91,1685.85,187.6,0.,0.,24.25
BCD 3 18.0X12.00X 91.0T
DEC 26.77,4.77,844.0,163.9,0.,0.,18.16
BCD 3 30.0X10.50X124.0I
DEC 27.53,10.34,2820.95,84.9,0.,0.,30.16
BCD 3 15.0X15.00X 95.0T
DEC 27.95,3.26,520.4,312.3,0.,0.,15.06
BCD 3 21.0X13.00X142.0I
DEC 28.58,6.03,1403.74,193.0,0.,0.,21.46
BCD 3 33.0X11.50X130.0I
DEC 29.15,11.52,3598.42,100.7,0.,0.,33.10
BCD 3 30.0X10.50X132.0I
DEC 29.28,10.37,3033.51,92.5,0.,0.,30.30
BCD 3 24.0X14.00X145.0I
DEC 29.34,6.92,1899.01,217.2,0.,0.,24.29
BCD 3 16.5X15.75X100.0T
DEC 29.40,3.67,683.6,345.8,0.,0.,16.50
BCD 3 27.0X14.00X145.0I
DEC 30.01,7.97,2390.22,203.5,0.,0.,26.88
BCD 3 15.0X15.00X105.0T
DEC 30.89,3.31,578.0,354.0,0.,0.,15.19
BCD 3 33.0X11.50X141.0I
DEC 31.36,11.28,3881.91,114.9,0.,0.,33.31
BCD 3 24.0X14.00X160.0I
DEC 32.33,7.00,2138.32,246.3,0.,0.,24.72
BCD 3 16.5X15.75X110.0T
DEC 32.36,3.71,754.1,391.2,0.,0.,16.63
BCD 3 27.0X14.00X160.0I
DEC 33.12,8.07,2671.83,229.0,0.,0.,27.08
BCD 3 33.0X11.50X152.0I
DEC 33.62,11.39,4258.86,128.1,0.,0.,33.50
BCD 3 36.0X12.00X150.0I
DEC 33.79,12.55,4870.24,125.2,0.,0.,35.84
BCD 3 18.0X16.50X115.0T
DEC 33.86,4.02,935.8,435.5,0.,0.,17.94
BCD 3 16.5X15.75X120.0T
DEC 35.26,3.73,822.5,437.2,0.,0.,16.75
BCD 3 30.0X15.00X172.0I
DEC 35.83,8.98,3541.84,275.0,0.,0.,29.88
BCD 3 36.0X12.00X160.0I
DEC 35.89,12.53,5230.68,137.7,0.,0.,36.00
```

```
BCD 3 18.0X16.50X122.5T
DEC 36.01,4.04,994.3,472.3,0.,0.,18.03
BCD 3 27.0X14.00X177.0I
DEC 36.75,8.19,3013.34,259.5,0.,0.,27.31
BCD 3 36.0X12.00X170.0I
DEC 37.96,12.53,5607.60,150.3,0.,0.,36.16
BCD 3 18.0X16.50X130.0T
DEC 38.28,4.07,1059.2,510.3,0.,0.,18.12
BCD 3 30.0X15.00X190.0I
DEC 39.48,9.05,3967.07,312.3,0.,0.,30.12
BCD 3 36.0X12.00X182.0I
DEC 40.69,12.62,6071.86,163.9,0.,0.,36.32
BCD 3 18.0X16.50X140.0T
DEC 41.16,4.07,1133.3,563.7,0.,0.,18.25
BCD 3 33.0X15.75X200.0I
DEC 42.21,10.25,5197.69,345.9,0.,0.,33.00
BCD 3 36.0X12.00X194.0I
DEC 43.43,12.69,6521.07,177.7,0.,0.,36.48
BCD 3 30.0X15.00X210.0I
DEC 43.65,9.15,4448.55,354.0,0.,0.,30.38
BCD 3 18.0X16.50X150.0T
DEC 44.09,4.13,1222.7,612.6,0.,0.,18.36
BCD 3 33.0X15.75X220.0I
DEC 46.20,10.20,5668.24,391.2,0.,0.,33.25
BCD 3 36.0X16.50X230.0I
DEC 48.56,11.10,6967.84,435.5,0.,0.,35.88
BCD 3 33.0X15.75X240.0I
DEC 50.27,10.29,6274.16,437.2,0.,0.,33.50
BCD 3 36.0X16.50X245.0I
DEC 51.56,11.14,7479.32,472.4,0.,0.,36.06
BCD 3 36.0X16.50X260.0I
DEC 54.79,11.20,8015.06,510.3,0.,0.,36.24
BCD 3 36.0X16.50X280.0I
DEC 58.73,11.24,8741.46,563.8,0.,0.,36.50
BCD 3 36.0X16.50X300.0I
DEC 63.01,11.37,9493.02,612.6,0.,0.,36.72
BCD 3 THERE IS NO BEAM
DEC -1.0,-1.0,-1.0,-1.0,-1.0,-1.0,
END 0
```

APPENDIX C

PROGRAM FOR SELECTING SCANTLINGS AND PLATING

```
        SAP M885-721-PROGRAM
        LST OFF
        PRG OFF
COMMON  SYN /25
MICMDL  SYN /'127
SQRT    SYN /356
COS     SYN /423
SIN     SYN /424
BLOCK   SYN /520
WOT     SYN /1376
        ORG /10570
START   CLA HANDL            0, 0, 15
        COM
        STD INDAA            0, 0, -16
        STD INDAB
        STD INDAC
        STD INDAD
        STD INDAE
        STD INDAF
        STD INDAG
        STD INDAH
        STD INDAI
        STD INDAJ
        CLA HANDL+1          0, 0, 31
        COM
        STD INDBA            0, 0, -32
        STD INDBB
        STD INDBC
        STD INDBD
        STD INDBE
```

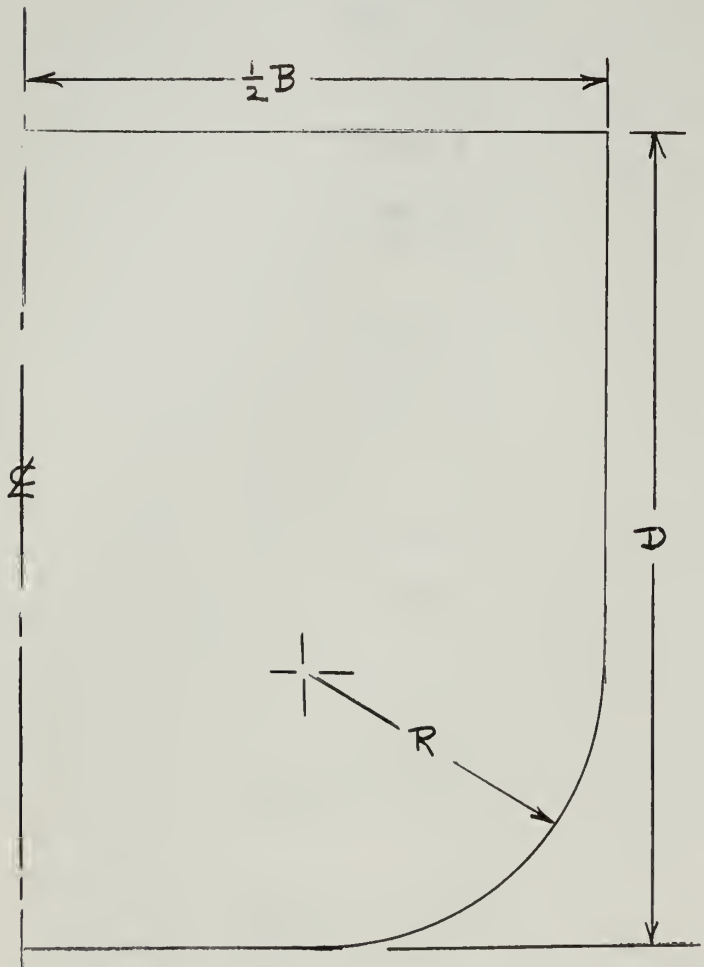
```
STD INDBF
STD INDBG
STD INDBH
STD INDBI
STD INDBJ
STD INDBK
STD INDBL
STD INDBM
STD INDBN
STD INDBO
STD INDBP
STD INDBQ
STD INDBR
STD INDBS
STD INDBT
STD INDBU
STD INDBV
STD INDBW
CLA HANDL+2          0, 0, 9
COM
STD INDCA            0, 0, -10
CLA HANDL+3          0, 0, 2
COM
STD INDDA            0, 0, -3
STD INDDB
STD INDDC

REM CONVERSION OF UNITS
```

```
LDQ INPUT          D (ft)
FMP CONST+5        12
STO INPUT          D (in)
LDQ INPUT+1        B (ft)
FMP CONST+5        12
STO INPUT+1        B (in)
LDQ INPUT+2        R (ft)
FMP CONST+5        12
STO INPUT+2        R (in)
LDQ INPUT+3        F (ft)
FMP CONST+5        12
STO INPUT+3        F (in)
LDQ INPUT+4        W (ft)
FMP CONST+5        12
STO INPUT+4        W (in)
LDQ INPUT+12       M1+ (ft-tons)
FMP CONST+5        12
STO INPUT+12       M1+ (in-tons)
LDQ INPUT+13       M1- (ft-tons)
FMP CONST+5        12
STO INPUT+13       M1- (ft-tons)
LDQ INPUT+14       Ho (ft)
FMP CONST+5        12
STO INPUT+14       Ho (in)
LDQ INPUT+12       M1+ (in-tons)
FMP CONST+29       2240
STO INPUT+12       M1+ (in-lbs)
LDQ INPUT+13       M1- (in-tons)
FMP CONST+29       2240
STO INPUT+13       M1- (in-lbs)
```

FIGURE 2

Parameters Which Describe the Hull Shape



HALF GIRTH DISTANCE $= B + D - 2R + \frac{\pi}{2}R$

$$= B + D - R(2 - \pi/2)$$

$$= B + D - 0.4292R$$

HALF SCANTLING SPACING:

$$\frac{b_0}{2} = \frac{1}{n_0}(B + D - 0.4292R) \qquad (1)$$

SUCCESIVE SCANTLING SPACINGS

$$bn = b_0 n_0, \quad b = b_0 \frac{n_0}{n} \qquad (2)$$

```
REM CALCULATION OF CONSTANT GEOMETRICAL PARAMETERS
EFM                                   ENTER FLOATING TRAP MODE
CLA INPUT+1                           B
FDP CONST+2                           2
STQ ASIDE+5                           ½B
CLA ASIDE+5                           ½B
FSB INPUT+2                           R
STO ASIDE+9                           ½B-R
FAD ASIDE+5                           ½B
FDP CONST+2                           2
STQ ASIDE+7                           ½(B-R)
CLA INPUT+12                          M1+
STO REMEM+5                           A1 (min)
CLA CONST+1                           1.0
STO TEMP+18
REM CALCULATION OF INITIAL LONGITUDINAL SPACING
LDQ INPUT+2                           R
FMP CONST+4                           -0.4292 =-2+π/2
FAD INPUT                             D
FAD INPUT+1                           B
FDP INPUT+8                           n
STQ ASIDE+8                           ½b0 = 1/n0(B+D-0.4292R)        (1)
FMP CONST+2                           2
STO ASIDE+1                           b0
STO ASIDE+2                           b = b0
CLA INPUT+8                           n0
STO ASIDE                             n = n0
REM CALCULATION OF ESTIMATED MOMENTS OF INERTIA
```

Initial estimate of total hull moment of inertia:

1. Assume neutral axes to be located at mid depth
2. Assume primary bending stresses at the extreme fibers to be 20,000 psi.

$$\sigma = \frac{Mc}{I} \qquad I = \frac{Mc}{\sigma} = \frac{M}{20000} \times \frac{D}{2} = \frac{MD}{40000}$$

Effective width of plating in compression:

Karman-Sechler formula as quoted in ref. 3.

$$\frac{\lambda}{t} = 1.70\sqrt{E/\sigma_{yp}}$$

	LDQ INPUT+12	M_1^+
	FMP INPUT	D
	FDP CONST+6	40000.0
	STQ REMEM	$I_1^+ = M_1^+ D/40000.0$ (FIRST EST) (3)
	LDQ INPUT+13	M_1^-
	FMP INPUT	D
	FDP CONST+6	40000.0
	STQ REMEM+1	$I_1^- = M_1^- D/40000.0$ (FIRST EST) (3)
	REM FIRST ESTIMATE OF LOCATION OF NEUTRAL AXES	
	CLA INPUT	D
	FDP CONST+2	2
	STQ REMEM+2	$z_c^+ = D/2$ (FIRST ESTIMATE)
	STQ REMEM+3	$z_c^- = D/2$ (FIRST ESTIMATE)
	REM CALCULATION OF EFFECTIVE WIDTH (KARMAN SECHLER)	
	CLA INPUT+18	E
	FDP INPUT+17	$\sigma_{\bar{yp}}$
	STQ TEMP	$E/\sigma_{\bar{yp}}$
	CLA TEMP	$E/\sigma_{\bar{yp}}$
	TSX SQRT,4	
	HTR	ERROR STOP
	STO TEMP	$\sqrt{E/\sigma_{\bar{yp}}}$
	LDQ TEMP	$\sqrt{E/\sigma_{\bar{yp}}}$
	FMP CONST+7	1.70
	STO ASIDE+10	$X/t = 1.70\sqrt{E/\sigma_{\bar{yp}}}$ (4)
	REM CALCULATIONS OF PARAMETERS OF LONGITUDINAL SPACING	
INSAA	LDQ ASIDE+2	b
	FMP ASIDE+2	b
	STO ASIDE+3	b^2

77
98

Effective breadth: (ref. 3)

Curve (a) of Figure 11 (multiple webs under uniform load) is used to determine $\lambda \leq b$

From (ref. 4) p. 2-31: assume an equation of the following form:

$$Y = \frac{\lambda}{b}, \quad X = \frac{cL}{B} \qquad c = 0.578 \text{ (FIXED ENDS)}$$

$$Y = a_1 + a_2(X-1) + a_3(X-1)(X-2) + a_4(X-1)(X-2)(X-3)$$

X	Y			
1	0.41			
		0.32		
2	0.73		-0.065	
		0.19		0.00
3	0.92		-0.065	
		0.06		
4	0.98			

$$a_1 = 0.41$$

$$a_2 = 0.32$$

$$a_3 = -0.065$$

$$a_4 = 0$$

$$Y = 0.41 + 0.32(X-1) - 0.065(X-1)(X-2)$$

$$= -0.04 + 0.515X - 0.065X^2$$

WHERE $0.5 < X < 4.5$

$$\frac{\lambda}{b} = -0.04 + 0.29767\,a/b - 0.02171546\,\frac{a^2}{b^2}$$

$$\lambda = -0.04b + 0.29767a - 0.02171546\,a^2/b \qquad (5)$$

for $a/b \geq 7.7855$, $\lambda = b$

```
      FDP CONST+5                          12.0
      FMP ASIDE+2                          b
      STO ASIDE+4                          b^3/12
      CLA ASIDE+2                          b
      FDP CONST+2                          2
      STQ ASIDE+8                          b/2
      REM EFFECTIVE BREADTH (SCHADE,SNAME TRANS.11-51)
      LDQ ASIDE+2                          b
      STQ ASIDE+11                         λ = b
      FMP CONST+8                          7.7855
      LDQ INPUT+5                          a
      TLQ INSAB ---┐                       if a < 7.7855b        λ < b
      TRA INSAC ---|---┐                   if a ≧ 7.7855b        λ = b
INSAB LDQ ASIDE+2 <-┘  |                   b
      FMP CONST+9      |                   -0.04
      STO TEMP         |                   -0.04b
      LDQ INPUT+5      |                   a
      FMP CONST+10     |                   0.29767
      FAD TEMP         |                   -0.04b
      STO TEMP         |                   -0.04b + 0.29767a
      LDQ INPUT+5      |                   a
      FMP INPUT+5      |                   a
      FDP ASIDE+2      |                   b
      FMP CONST+11     |                   -0.02171546
      FAD TEMP         |                   -0.04b + 0.29767a
      STO ASIDE+11     |                   λ = -0.04b + 0.29767 a
                       |                       -0.02171546 a^2/b      (5)
INSAC LXD NIX,1 <------┘                   RESET INDEX 1
      REM NUMBERING OF LOCATIONS, KEEL IS LOCATION ZERO
```

Locations are numbered consecutively from the keel (o) around the girth of the hull to the centerline at the deck, (n). The next two locations beyond the one designated (n) are arbitrarily given coordinates (-1, -1). This was done to assist in transferring out of the numerous loops found later in the program. The above simplifies indexing procedures since all other coordinates are positive.

```
      CLA NIX                                  0.0
INSAD STO LOC,1                                c = 0, 1, 2, . . . , n
      FAD CONST+1                              1.0
INDAA TXI INSAE,1                   (-16)
INSAE CAS ASIDE                                COMPARE c WITH n
      TRA INSAF                                if c > n, LEAVE LOOP
      NOP
      TRA INSAD                                if c ≤ n
INSAF CLA CONST                                -1.0
      REM COORDINATES OF TWO LOCATIONS BEYOND THE LAST PERTINENT
      REM LOCATION ARE SET AT MINUS ONE TO FACILITATE PROGRAMMING
      STO LOC+1,1                              Z_n+1 = -1.0
      STO LOC+2,1                              Y_n+1 = -1.0
      STO LOC+17,1                             Z_n+2 = -1.0
      STO LOC+18,1                             Y_n+2 = -1.0
      REM CALCULATION OF LOCATION COORDINATES
      REM COORDINATES ALONG BOTTOM
      LXD NIX,1                                RESET INDEX 1
      CLA NIX                                  0.0
INSAG STO LOC+2,1                              Y = 0, b/2, b, 3b/2, 2b, . . .
      FAD ASIDE+8                              b/2
      STZ LOC+1,1                              Z = 0
INDAB TXI INSAH,1                   (-16)
INSAH CAS ASIDE+9                              COMPARE Y WITH 1/2 B-R
      TRA INSAI                                if Y > 1/2 B-R, LEAVE LOOP
      NOP
      TRA INSAG                                if Y ≤ 1/2 B-R
      REM COORDINATES AT TURN OF BILGE
```

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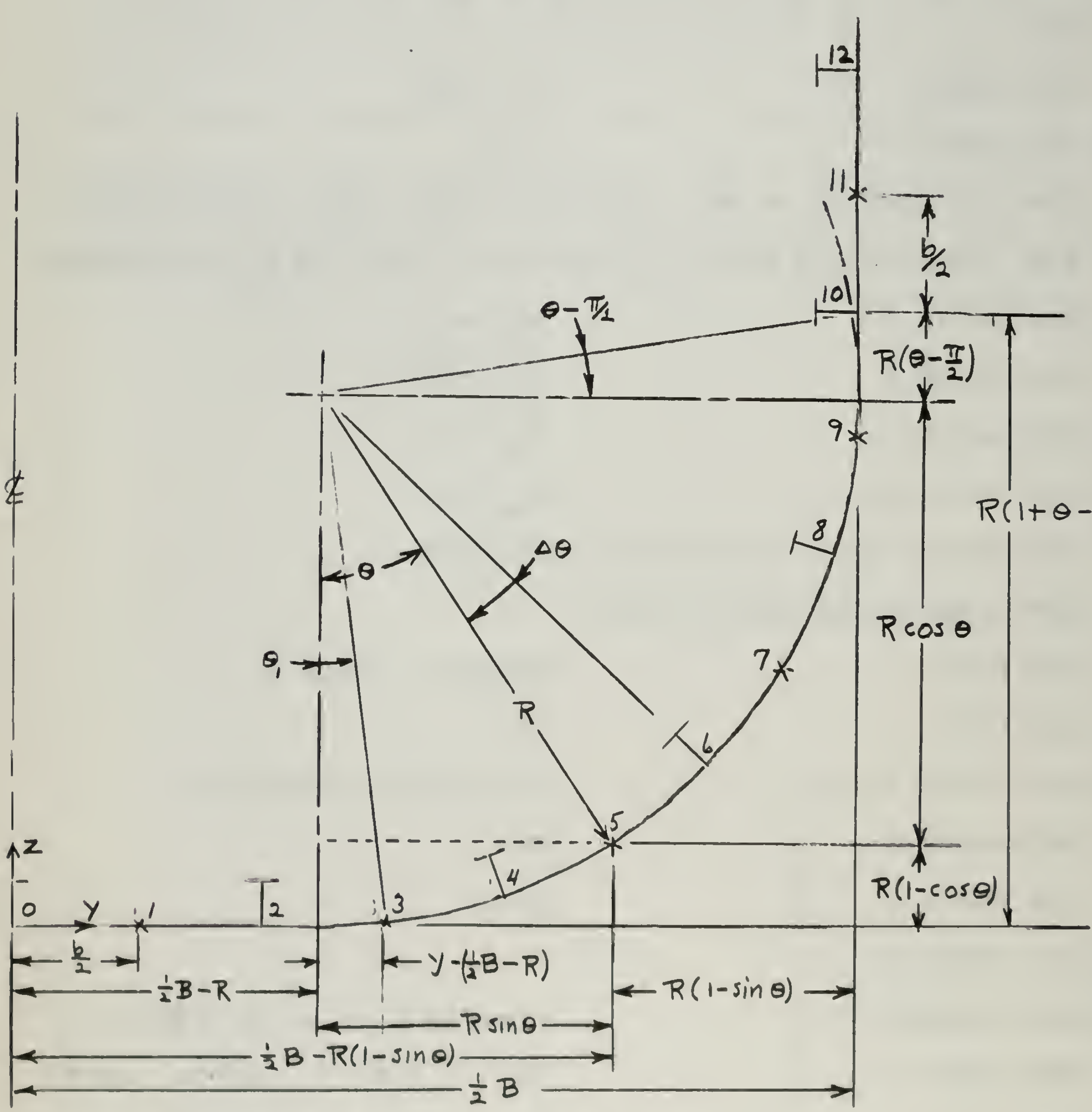
FIGURE 3

Coordinates along the bottom, turn of the bilge and side of the hull



$Y < \frac{1}{2}B - R: \quad Y = c\,\frac{b}{2} \qquad z = 0 \qquad c = 1, 2, 3, 4, \ldots$

$0 < \theta < \frac{\pi}{2}: \quad Y = \frac{1}{2}B - R(1 - \sin\theta) \qquad z = R(1 - \cos\theta)$ (6) (7)

$\frac{\pi}{2} < \theta,\ z < D: \quad Y = \frac{1}{2}B \qquad z = R + R\left(\theta - \frac{\pi}{2}\right) + c\,\frac{b}{2} \qquad c = 1, 2, 3, 4, \ldots$ (8) (9)

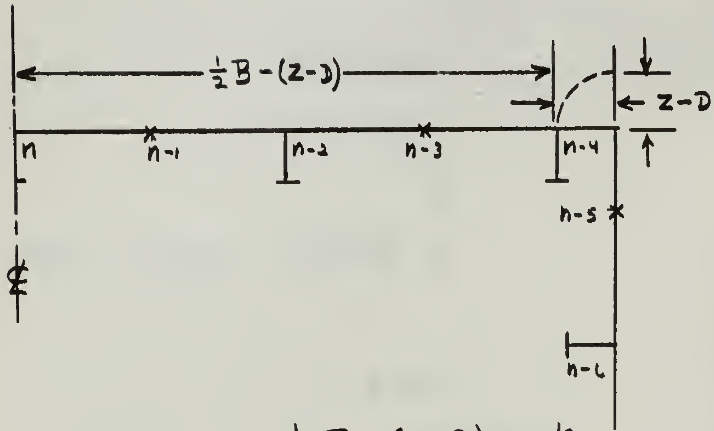
58

INSAI	FSB	ASIDE+9	$\frac{1}{2}B - R$
	FDP	INPUT+2	R
	STQ	TEMP	$\theta_1 = \frac{1}{R}[Y - (\frac{1}{2}B - R)]$
	CLA	ASIDE+8	$\frac{1}{2}b$
	FDP	INPUT+2	R
	STQ	TEMP+1	$\Delta\theta = b/2R$
INSAJ	LDQ	CONST+12	$1.5708 = \frac{1}{2}\pi$
	CLA	TEMP	θ
	TLQ	INSAK	if $\theta > \frac{1}{2}\pi$, LEAVE LOOP
	TSX	SIN,4	
	STO	TEMP+2	$\sin\theta$
	CLA	TEMP	θ
	TSX	COS,4	
	STO	TEMP+3	$\cos\theta$
	CLA	CONST+1	1.0
	FSB	TEMP+3	$\cos\theta$
	STO	TEMP+4	$1 - \cos\theta$
	LDQ	TEMP+4	$1 - \cos\theta$
	FMP	INPUT+2	R
	STO	LOC+1,1	$z = R(1 - \cos\theta)$ (7)
	CLA	TEMP+2	$\sin\theta$
	FAD	CONST	-1.0
	STO	TEMP+4	$\sin\theta - 1$
	LDQ	TEMP+4	$\sin\theta - 1$
	FMP	INPUT+2	R
	FAD	ASIDE+5	$\frac{1}{2}B$
	STO	LOC+2,1	$y = \frac{1}{2}B + R(\sin\theta - 1)$ (6)
	CLA	TEMP	θ

62 62

FIGURE 4

Coordinates along the Deck

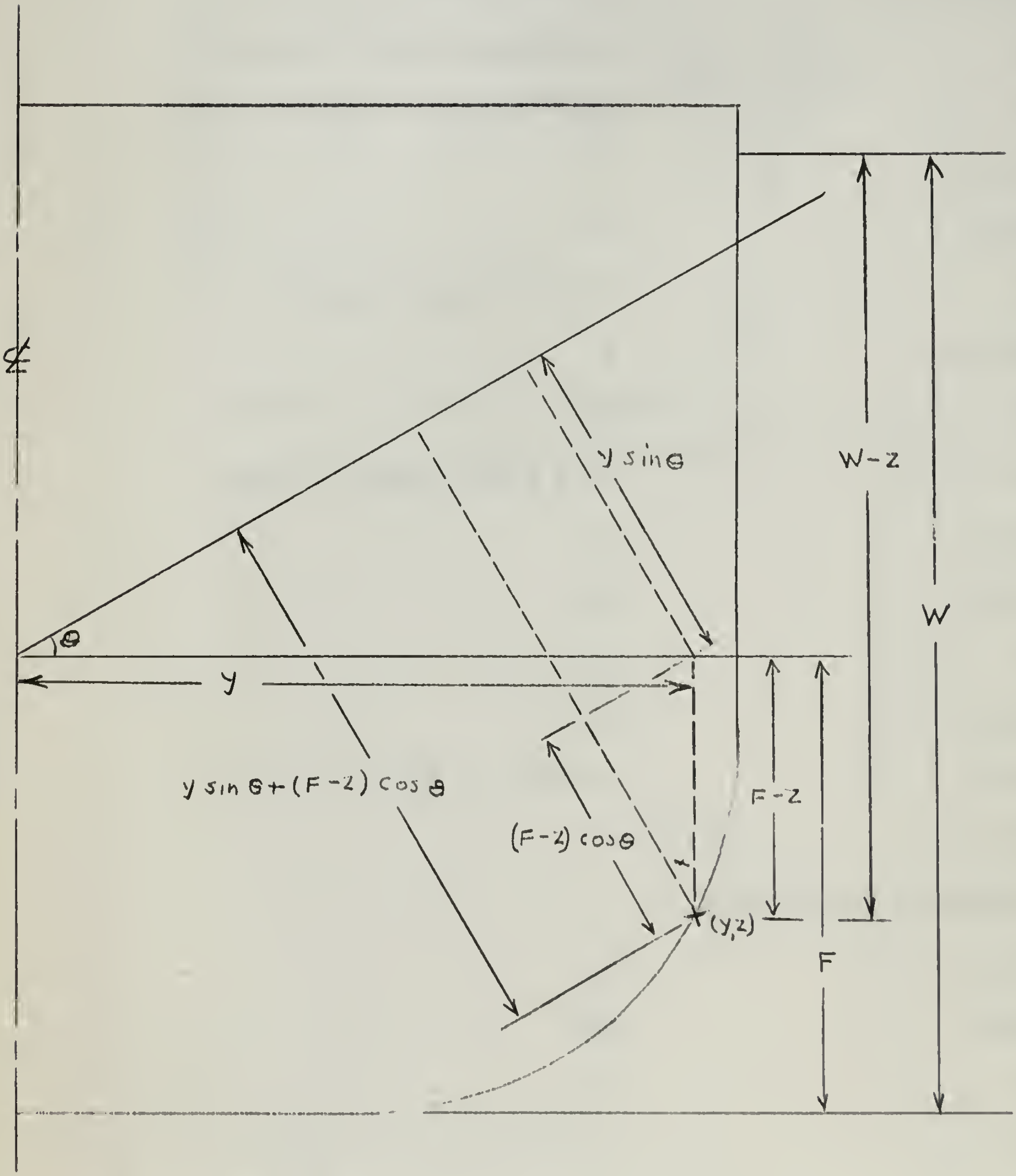


$$Z=D: \quad \left.\begin{aligned} Y &= \tfrac{1}{2}B-(Z-D)-c\tfrac{b}{2} \\ &= \tfrac{1}{2}B+D-Z-c\tfrac{b}{2} \end{aligned}\right\} \; c = 1, 2, 3, \ldots \qquad (10)$$

```
      FAD TEMP+1                              ΔΘ
      STO TEMP                                Θ
INDAC TXI INSAJ,1                  (-16)
      REM COORDINATES ALONG SIDE OF HULL
INSAK FSB CONST+12                            1.5708 = π/2
      STO TEMP                                Θ - π/2
      LDQ TEMP                                Θ - π/2
      FMP INPUT+2                             R
      FAD INPUT+2                             R
      STO TEMP                                Z = R + R(Θ - π/2)  (9)
INSAL CLA TEMP                                Z
      LDQ INPUT                               D
      TLQ INSAM                               if Z > D, LEAVE LOOP
      STO LOC+1,1                             Z
      FAD ASIDE+8                             ½b
      STO TEMP                                Z
      CLA ASIDE+5                             B/2
      STO LOC+2,1                             Y = B/2   (8)
INDAD TXI INSAL,1                  (-16)
      REM COORDINATES ALONG DECK
INSAM CLA INPUT                               D
      FAD ASIDE+5                             B/2
      FSB TEMP                                Z
      STO TEMP                                Y = ½B + D - Z   (10)
INSAN CLA TEMP                                Y
      TMI INSAO                               if Y < 0, LEAVE LOOP
      STO LOC+2,1                             Y
      FSB ASIDE+8
```

FIGURE 5

Hydrostatic Heads



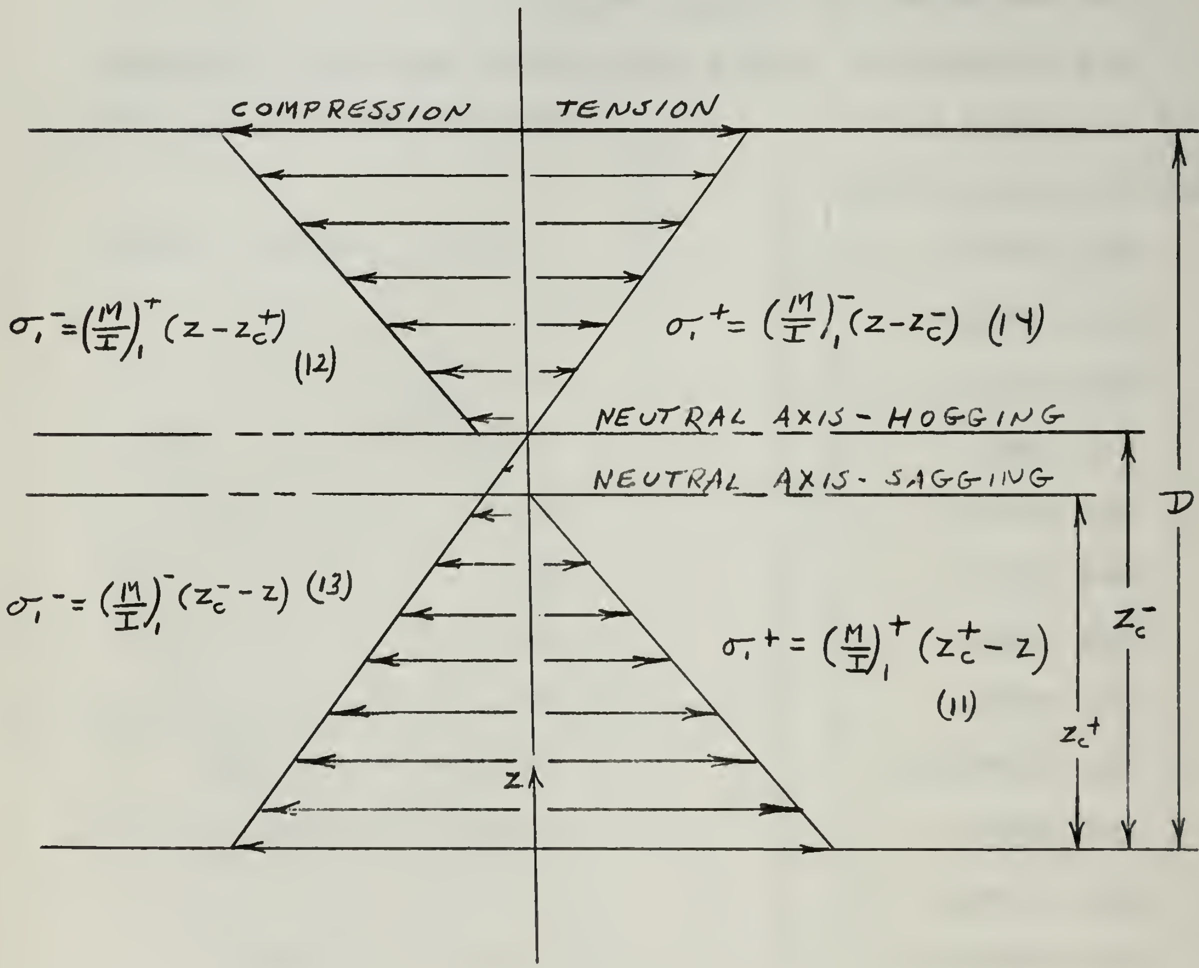
$$H_w = W - z \qquad (10)$$

$$H_\theta = y \sin\theta + (F - z)\cos\theta \qquad (11)$$

```
                                   62.     62
         STO  TEMP                                      Y
         CLA  INPUT                                     D
         STO  LOC+1,1                                   Z=D
INDAE    TXI  INSAN,1                          (-16)
         REM  BEGINNING OF GENERAL PROGRAM
         REM  CALCULATION OF MAX HYDROSTATIC HEAD EACH LOCATION
INSAO    LXD  NIX,1                                     RESET INDEX 1
INSAP    CLA  LOC+1,1                                   Z
         TMI  INSAS                                     if Z=-1 LEAVE LOOP
         CLA  INPUT+4                                   W
         FSB  LOC+1,1                                   Z
         STO  TEMP                                      Hw=W-Z           (9)
         CLA  INPUT+3                                   F
         FSB  LOC+1,1                                   Z
         STO  TEMP+1                                    F-Z
         LDQ  TEMP+1                                    F-Z
         FMP  CONST+13                                  0.8660 = COS 30°
         STO  TEMP+1                                    0.8660(F-Z)
         LDQ  LOC+2,1                                   Y
         FMP  CONST+14                                  0.50 = SIN 30°
         FAD  TEMP+1                                    0.8660(F-Z)      (10)
         CAS  INPUT+14                                  COMPARE Hθ WITH Hw
         TRA  INSAQ                                     if Hθ > Hw
         NOP
         CLA  INPUT+14                                  Hw if Hw ≥ Hθ
INSAQ    CAS  TEMP                                      COMPARE LARGER H WITH Ho
         TRA  INSAR                                     if Ho > Hθ AND Hw
         NOP
                                  66   66    66
```

FIGURE 6

Distribution of Stresses due to Ship Bending Moments



```
      CLA  TEMP                                  Ho  if  Ho > He  AND  Hw
INSAR STO  LOC+15,1                              THE LARGEST VALUE OF H
INDAF TXI  INSAP,1                     (-16)
      REM  CALCULATION OF SHIP (PRIMARY) BENDING STRESSES
INSAS LXD  NIX,1                                 RESET  INDEX  1
      CLA  INPUT+12                              M1+
      FDP  REMEM                                 I1+
      STQ  REMEM+10                              (M/I)1+
      CLA  INPUT+13                              M1-
      FDP  REMEM+1                               I1-
      STQ  REMEM+11                              (M/I)1-
      REM  STRESSES DUE TO POSITIVE SHIP BENDING MOMENT
INSAT CLA  REMEM+2                               zc+
      FSB  LOC+1,1                               z
      TMI  INSAU                                 if  z > zc+,  LEAVE  LOOP
      STO  TEMP                                  zc+ - z
      LDQ  TEMP                                  zc+ - z
      FMP  REMEM+10                              (M/I)1+
      STO  LOC+8,1                               σ1+ = (M/I)1+ (zc+ - z)      zc+ > Z
                                                                                (11)
INDAG TXI  INSAT,1                     (-16)
INSAU CLA  LOC+1,1                               z
      TMI  INSAV                                 if  z = -1,  LEAVE  LOOP
      FSB  REMEM+2                               zc+
      STO  TEMP                                  z - zc+
      LDQ  TEMP                                  z - zc+
      FMP  REMEM+10                              (M/I)1+
      STO  LOC+9,1                               σ1- = (M/I)1+ (z - zc+)      zc+ < Z
                                                                                (12)
INDAH TXI  INSAU,1                     (-16)

           68     94    66
                  95
```

Bryan Buckling criteria for plates loaded in end compression, simple support all edges.

$$\sigma_{cr} = \frac{K\pi^2 E t^2}{12(1-\mu^2)b^2}$$

$a/b > 1.0 : K = 4$ $\quad E = 30 \times 10^6$ psi

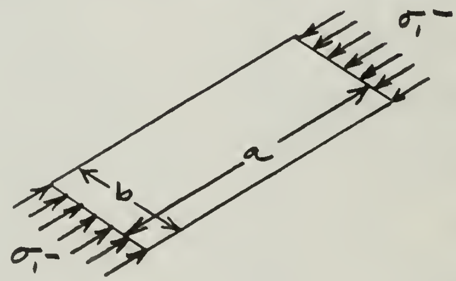
$a/b < 1.0 : K > 4$ $\quad \mu = 0.3$

$$\sigma_{cr} = \frac{4 \times 9.87 \times 30 \times 10^6 \, t^2}{12(1-0.09)b^2} = 108.46155 \times 10^4 \frac{t^2}{b^2}$$

$$t \geq \frac{b\sqrt{\sigma_{cr}}}{10414}, \quad (K = 4)$$

SINCE LOAD FACTORS OF SAFETY ARE USED LET $\sigma_1^- = \sigma_{cr}$

$$\therefore t \geq \frac{b\sqrt{\sigma_1^-}}{10414}$$



66

```
     REM STRESSES DUE TO NEGATIVE SHIP BENDING MOMENT
INSAV LXD NIX,1                   RESET INDEX 1
INSAW CLA REMEM+3                 zc-
      FSB LOC+1,1                 z
      TMI INSAX                   if z > zc-
      STO TEMP                    zc- - z
      LDQ TEMP                    zc- - z
      FMP REMEM+11                (M/I)1-
      STO LOC+9,1                 σ1- = (M/I)1- (zc- - z)      zc- > z
                                                               (13)
INDAI TXI INSAW,1       (-16)
INSAX CLA LOC+1,1                 z
      TMI INSAY                   if z = -1 LEAVE LOOP
      FSB REMEM+3                 zc-
      STO TEMP                    z - zc-
      LDQ TEMP                    z - zc-
      FMP REMEM+11                (M/I)1-
      STO LOC+8,1                 σ1+ = (M/I)1- (zc- - z)      zc- < z
                                                               (14)
INDAJ TXI INSAX,1       (-16)
     REM SELECTION OF HULL PLATING BRYAN BUCKLING CRITERIA
INSAY LXD NIX,3                   RESET INDEX 1
INSAZ CLA LOC+17,1                zp
      TMI INSBC                   if zp = -1, LEAVE LOOP
      CLA LOC+25,1                σ1-
      TSX SQRT,4
      HTR                         ERROR STOP
      FDP CONST+15                10414.0
      FMP ASIDE+2                 b
      STO TEMP                    t(min) = b √σ1- / 10414.0
```

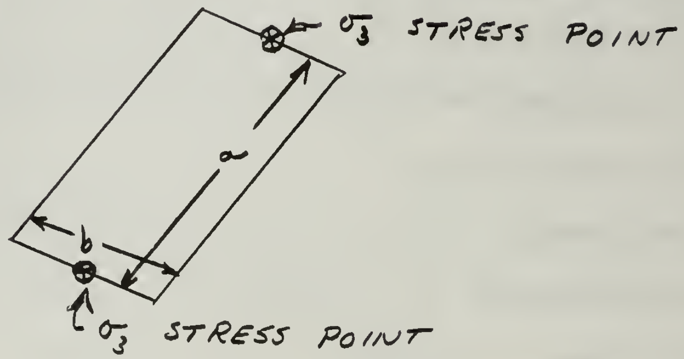
71   11

Tertiary Stress Calculations (ref. 5). Stress due to lateral load on plate.

$$\sigma_3 = \tfrac{1}{2} K \rho H \frac{b^2}{t^2} \times \frac{1}{144} \qquad \frac{a}{b} > 1.6 \qquad K = 0.685$$

$$= \tfrac{1}{2} \times 0.685 \times 64 \left(\frac{lb}{ft^3}\right) \times H\,(in) \times \frac{1}{1728}\left(\frac{ft^3}{in^3}\right)\frac{b^2}{t^2} = 0.0127\, H \frac{b^2}{t^2}$$

$$\sigma_3 = 0.0127\, H \frac{b^2}{t^2} \qquad (16)$$



Stress schedule in plating midway between longitudinals σ_2 is specified by INPUT+19.

$$\sigma_3 = \sigma_3^{+} = \sigma_3^{-} \qquad \sigma_1^{+} + \sigma_2 + \sigma_3 \leq \sigma_{YP}^{+} \quad (17)$$

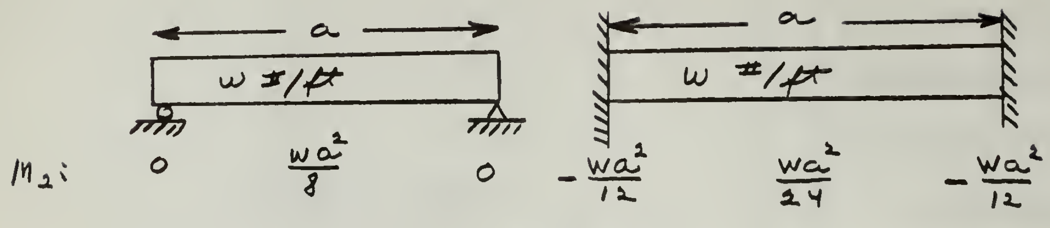
$$\sigma_1^{-} - \sigma_2 + \sigma_3 \leq \sigma_{YP}^{-} \quad (18)$$

REM SELECTION OF PLATING THICKNESS FROM STD STOCK

INSBA	CLA	PLATE,2		PLATE DESIG (LB/FT^2)
	TMI	INDDC+2		if $LB/FT^2 = -1$, SKIP
	CLA	TEMP		t (min)
	CAS	PLATE+1,2		COMPARE t (min) WITH t (AVAILABLE
INDDA	TXI	INSBA,2	(−3)	if t (min) > t (AVAIL)
	REM	TERTIARY STRESS CALCULATION		
	NOP			
INSBB	LDQ	ASIDE+3		b^2
	FMP	LOC+31,1		H_p
	FDP	PLATE+2,2		t^2
	FMP	CONST+16		0.0127
	STO	LOC+26,1		$\sigma_3 = 0.0127\, H_p \frac{b^2}{t^2}$ (16)
	STO	LOC+58,1		σ_3
	REM	STRESS SCHEDULE BETWEEN LONGITUDINALS		
	FAD	LOC+24,1		σ_1^+
	FAD	INPUT+19		σ_2
	CAS	INPUT+16		COMPARE $\sigma_1^+ + \sigma_2 + \sigma_3$ WITH σ_{YP}^+ (17)
INDDB	TXI	INSBB,2	(−3)	
	NOP			
	CLA	LOC+25,1		σ_1^-
	FAD	LOC+26,1		σ_3
	FSB	INPUT+19		σ_2
	CAS	INPUT+17		COMPARE $\sigma_1^- - \sigma_2 + \sigma_3$ WITH σ_{YP}^-
INDDC	TXI	INSBB,2	(−3)	(18)
	NOP			
	CLA	PLATE,2		PLATE DESIGNATION (LB/FT^2)
	STO	LOC+19,1		" " (LB/FT^2)

```
                 68   68
      CLA PLATE+1,2                      t
      STO LOC+20,1                       t
      STO LOC+52,1                       t
      CLA PLATE+2,2                      t²
      STO LOC+21,1                       t²
      LXD NIX,2                          RESET INDEX 2
INDBA TXI INSAZ,1            (-32)
INSBC LXD NIX,3                          RESET INDICES 1 AND 2
      REM PLATE THICKNESSES TO BE ASSOCIATED WITH SCANTLINGS
      LDQ LOC+20                         t
      STQ LOC+7                          t
      FMP ASIDE+10                       λ̄/t
      CAS ASIDE+2                        COMPARE λ̄ WITH b
      CLA ASIDE+2                        b
      NOP
      STO LOC+14                         THE SMALLER OF λ̄ OR b
INDBB TXI INSBD,1            (-32)
INSBD CLA LOC+1,1                        z_s
      TMI INSBF                          if z_s=-1 LEAVE LOOP
      CLA LOC-12,1                       t
      FAD LOC+20,1                       t
      FDP CONST+2                        2
      STQ LOC+7,1                        t
      STQ LOC+39,1                       t
      FMP ASIDE +10                      λ̄/t
      CAS ASIDE +2                       COMPARE λ̄/t WITH b
      CLA ASIDE +2                       b
      NOP
                 73   73
```

Secondary Bending Moments

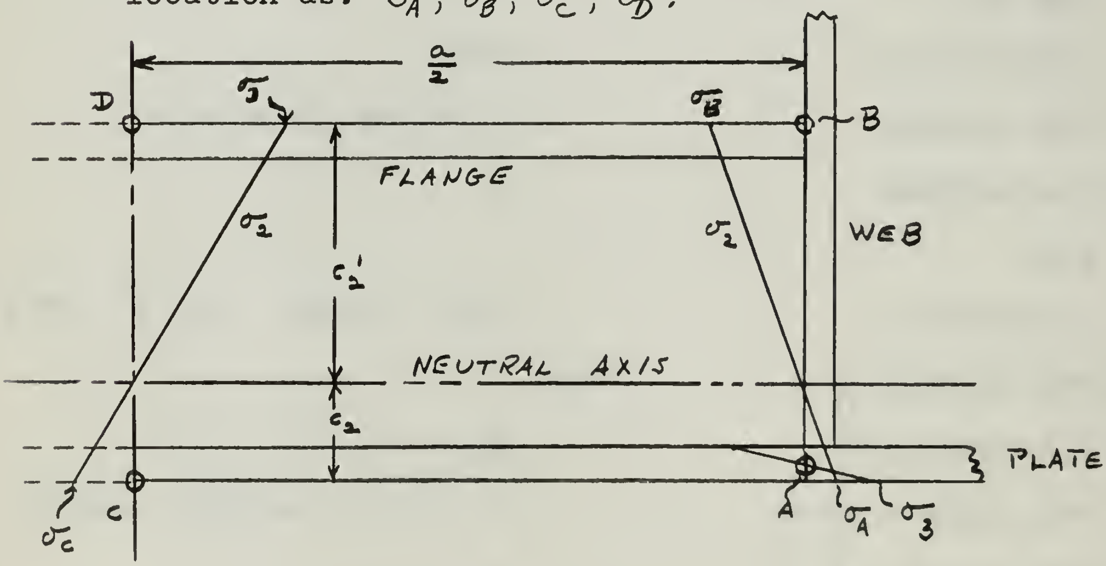


$$w = pb = H \times \frac{64b}{1728} = \frac{Hb}{27} \ \#/\text{FT}$$

$$M_2^+ = \frac{wa^2}{12} = \frac{Ha^2b}{324}, \quad M_2^- = \frac{wa^2}{8} = \frac{3}{2} \times \frac{wa^2}{12} = \frac{3}{2} M_2^+$$

FIGURE 7. Stresses due to Secondary Bending Moments

Stresses due to Secondary Bending Moments are referred to by location as: σ_A, σ_B, σ_C, σ_D.



PT	EQN	STRESS SCHEDULE
A	19	$\sigma_{YP}^+ \geq \sigma_1^+ + \sigma_A + \sigma_3$
	20	$\sigma_{YP}^- \geq \sigma_1^- - \sigma_A + \sigma_3$
B	21	$\sigma_{YP}^+ \geq \sigma_1^+ - \sigma_B$
	22	$\sigma_{YP}^- \geq \sigma_1^- + \sigma_B$
C	23	$\sigma_{YP}^+ \geq \sigma_1^+ - \sigma_C = \sigma_1^+ - 3/2\ \sigma_A$
	24	$\sigma_{YP}^- \geq \sigma_1^- + \sigma_C = \sigma_1^- + 3/2\ \sigma_A$
D	25	$\sigma_{YP}^+ \geq \sigma_1^+ + \sigma_D = \sigma_1^+ + 3/2\ \sigma_B$
	26	$\sigma_{YP}^- \geq \sigma_1^- - \sigma_D = \sigma_1^- - 3/2\ \sigma_B$

71 71

	STO	LOC+14,1	THE SMALLER OF λ^- OR b
	TRA	INDBB	
INSBF	LXD	NIX,1	RESET INDEX 1
	REM	CALCULATION OF SECONDARY BENDING MOMENTS	
	LDQ	INPUT+5	a
	FMP	INPUT+5	a
	FDP	CONST+19	324
	FMP	ASIDE+2	b
	STO	TEMP	$a^2b/324$
	LDQ	TEMP	$a^2b/324$
INSBG	CLA	LOC+1,1	z
	TMI	INSBH	if $z=-1$ LEAVE LOOP
	LDQ	LOC+15,1	H_5
	FMP	TEMP	$a^2b/324$
	STO	LOC+10,1	$M_2 = H_5 a^2 b/324$
INDBC	TXI	INSBG,1 (-32)	
INSBH	LXD	NIX,1	RESET INDEX 1
	REM	REQUIRED SECTION MODULI	
INSBI	CLA	LOC+1,1	z
	TMI	INSBN	if $z=-1$, LEAVE LOOP
	CLA	INPUT+17	σ_{YP}^-
	FSB	LOC+9,1	σ_1^-
	FDP	CONST+26	1.5
	STQ	TEMP	σ_A (24)
	CLA	INPUT+16	σ_{YP}^+
	FSB	LOC+8,1	σ_1^+
	FSB	LOC+26,1	σ_3
	CAS	TEMP	COMPARE σ_A (17) WITH σ_A (24)

76 76

Continuation of Discussion of Secondary Bending Stresses

DISREGARD:

COMPARING EQNS (19) AND (23): $\sigma_1^+ + \sigma_A > \sigma_1^+ - \frac{3}{2}\sigma_A$: EQN (23)

(22) (26) $\sigma_1^- + \sigma_B > \sigma_1^- - \frac{3}{2}\sigma_B$: EQN (26)

(21) (25) $\sigma_1^+ - \sigma_B < \sigma_1^+ + \frac{3}{2}\sigma_B$: EQN (21)

σ_A IS DEFINED BY INPUT + 19, ∴ EQN (19) COULD BE DISREGARDED. THE FOLLOWING STRESS SCHEDULE EQUATIONS ARE PERTINENT:

(19) $\sigma_A \leq \sigma_{YP}^+ - \sigma_1^+ - \sigma_B$ (22) $\sigma_B \leq \sigma_{YP}^- - \sigma_1^-$

(24) $\sigma_A \leq \frac{2}{3}(\sigma_{YP}^- - \sigma_1^-)$ (25) $\sigma_B \leq \frac{2}{3}(\sigma_{YP}^+ - \sigma_1^+)$

(20) $\sigma_A \geq \sigma_1^- + \sigma_B - \sigma_{YP}^-$

Buship's criterion for span/radius of gyration is that $a/k \leq 50$ at the base line, $a/k \leq 50$ at the upper strength deck and that a/k varies linearity between the base line and the strength deck (ref. 6).

Moncriel's equation for a/k with a factor of safety of 1.0

$$\frac{a}{k} \leq \sqrt{\frac{9.6E(\sigma_{ULT} - 1.6\sigma_1^-)}{\sigma_1^-(\sigma_{ULT} - 0.88\sigma_1^-)}} = 16970.6\sqrt{\frac{\sigma_{ULT} - 1.6\sigma_1^-}{\sigma_1^-(\sigma_{ULT} - 0.88\sigma_1^-)}} \quad (27)$$

The above values of a/k are compared and the smaller or more conservative value is used in subsequent calculations.

CLA TEMP	σ_A (24)
NOP	
STO TEMP	THE SMALLER OF σ_A(19) OR σ_A (24) $= \sigma_2$
CLA LOC+10,1	M_2
FDP TEMP	σ_2
STQ LOC+12,1	I_2/c_2 (min) $= M_2/\sigma_2$
CLA INPUT+16	σ_{YP}^{+}
FSB LOC+8,1	σ_1^{-}
FDP CONST+26	1.5
STQ TEMP	σ_B (25)
CLA INPUT+17	σ_{YP}^{-}
FSB LOC+9,1	σ_1^{-}
CAS TEMP	COMPARE σ_B(22) WITH σ_B(25)
CLA TEMP	σ_B ([illegible]
NOP	
STO TEMP	THE SMALLER OF σ_B(22) OR σ_B (25) $= \sigma_2'$
CLA LOC+10,1	M_2
FDP TEMP	σ_2'
STQ LOC+13,1	I_2/c_2' (min) $= M_2/\sigma_2'$
REM SPAN/RADIUS OF GYRATION, BUSHIPS CRITERION	
CLA LOC+1,1	Z
FDP INPUT	D
FMP CONST+25	20.0
FAD CONST+17	30.0
STO LOC+6,1	$a/k\,(\text{MAX}) = 30 + 20\frac{Z}{D}$
REM SPAN/RADIUS OF GYRATION, MONCRIEFF FACTOR OF SAFETY=1.0	
CLA LOC+9,1	σ_1^{-}
FSB INPUT+19	σ_2

73 73

	TMI	INDBD	if $\sigma_1^- < \sigma_2$ SKIP
	LDQ	LOC+9,1	σ_1^-
	FMP	CONST+22	-1.6
	FAD	INPUT+15	σ_{ULT}
	TMI	INDBD	if $\sigma_{ULT} < 1.6\,\sigma_1^-$ SKIP
	FDP	LOC+9,1	σ_1^-
	STQ	TEMP	$\frac{1}{\sigma_1^-}(\sigma_{ULT} - 1.6\,\sigma_1^-)$
	LDQ	LOC+9,1	σ_1^-
	FMP	CONST+23	-0.88
	FAD	INPUT+15	σ_{ULT}
	STO	TEMP+1	$\sigma_{ULT} - 0.88\,\sigma_1^-$
	CLA	TEMP	$\frac{1}{\sigma_1^-}(\sigma_{ULT} - 1.6\,\sigma_1^-)$
	FDP	TEMP+1	$\sigma_{ULT} - 0.88\,\sigma_1^-$
	STQ	TEMP	$\left.\right\}\ \dfrac{\sigma_{ULT} - 1.6\,\sigma_1^-}{\sigma_1^-(\sigma_{ULT} - 0.88\,\sigma_1^-)}$
	CLA	TEMP	
	TSX	SQRT,4	
	TRA	INDBD	ERROR SKIP
	STO	TEMP	$\left.\right\}\sqrt{\dfrac{\sigma_{ULT} - 1.6\,\sigma_1^-}{\sigma_1^-(\sigma_{ULT} - 0.88\,\sigma_1^-)}}$ (27)
	LDQ	TEMP	
	FMP	CONST+24	16970.6
	REM	COMPARISON OF RADII OF GYRATION, THE LESSER VALUE IS USED	
	CAS	LOC+6,1	COMPARE a/k WITH a/k (MAX)
	CLA	LOC+6,1	a/k (MAX)
	NOP		
INSBM	STO	LOC+6,1	THE SMALLER VALUE OF a/k
INDBD	TXI	INSBI,1	(-32)
	REM	PLATE PARAMETERS FOR SELECTION OF SCANTLINGS	
INSBN	LXD	NIX,3	RESET INDICES 1 AND 2

```
INSBO CLA LOC+1,1          z
      TMI INSBQ            if z = -1, LEAVE LOOP
      LXD NIX,2            RESET INDEX 2
      CLA LOC+7,1          t
      FDP CONST+2          2
      STQ TEMP+6           ½t
      LDQ LOC+7,1          t
      FMP ASIDE+11         λ
      STO TEMP             λt
      LDQ TEMP             λt
      FMP LOC+7,1          t
      FDP CONST+5          12
      FMP LOC+7,1          t
      STO TEMP+1           λt³/12
      LDQ LOC+14,1         λ⁻
      FMP LOC+7,1          t
      STO TEMP+2           λ⁻t
      FDP CONST+5          12
      FMP LOC+14,1         λ⁻
      STO TEMP+7           (λ⁻)²t/12
      LDQ TEMP+7           (λ⁻)²t/12
      FMP LOC+14,1         λ⁻
      STO TEMP+7           (λ⁻)³t/12
      CLA TEMP+1           λt³/12
      FDP ASIDE+11         λ
      FMP LOC+14,1         λ⁻
      STO TEMP+3           λ⁻t³/12
      REM CONVERSION OF BEAM CHARACTERISTICS TO BEAM PLATE
```

84 84

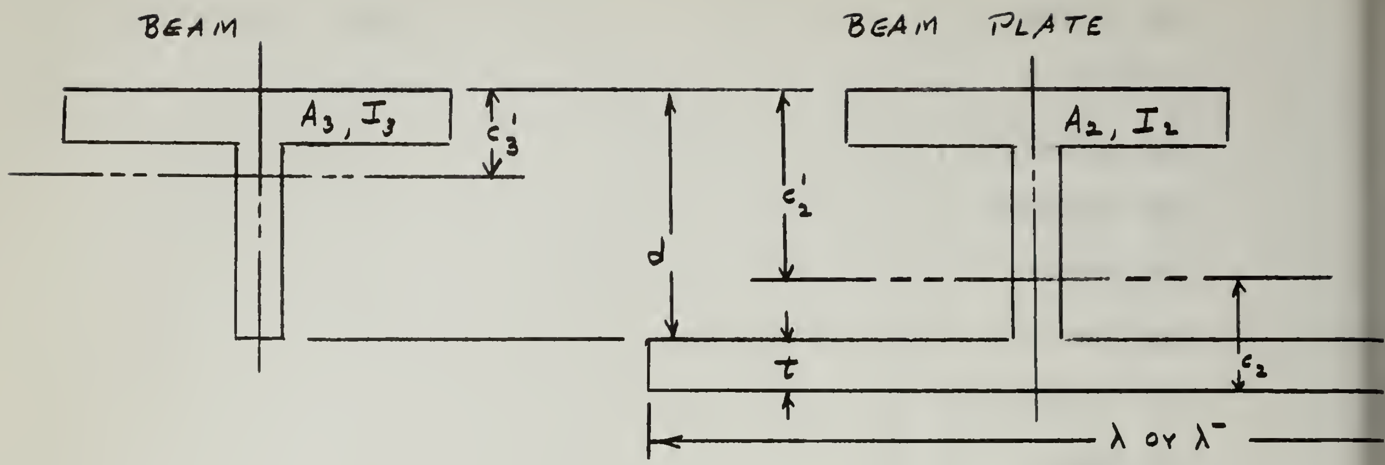


FIGURE 8

Beam, Beam Plate Geometry and Dimensions

$$A_2 = A_3 + \lambda t \quad (28)$$

$$A_2^- = A_3 + \lambda^- t \quad (29)$$

$$c_2' = \frac{1}{A_2}\left[c_3' A_3 + \lambda t\left(d + \frac{t}{2}\right)\right]$$

$$c_2'^- = \frac{1}{A_2^-}\left[c_3' A_3 + \lambda^- t\left(d + \frac{t}{2}\right)\right]$$

$$= c_3' \frac{(A_2 - \lambda t)}{A_2} + \frac{\lambda t}{A_2}\left(d + \frac{t}{2}\right)$$

$$= c_3' - \frac{\lambda t}{A_2} c_3' + \frac{\lambda t}{A_2}\left(d + t/2\right)$$

$$c_2' = c_3' + \frac{\lambda t}{A_2}\left(d + t/2 - c_3'\right) \quad (30)$$

$$c_2'^- = c_3' + \frac{\lambda^- t}{A_2}\left(d + t/2 - c_3'\right) \quad (31)$$

$$c_2 = d + t - c_2' \quad (32)$$

$$c_2^- = d + t - c_2'^- \quad (33)$$

$$I_2 = I_3 + A_3(c_2' - c_3')^2 + \frac{\lambda t^3}{12} + \lambda t\left(c_2 - \frac{t}{2}\right)^2 \quad (34)$$

$$I_2^- = I_3 + A_3(c_2' - c_3')^2 + \frac{\lambda^- t^3}{12} + \lambda^- t\left(c_2^- - \frac{t}{2}\right)^2 \quad (35)$$

$$I_{2YY} = I_{3YY} + \frac{b^3 t}{12} \quad (36)$$

$$I_{2YY}^- = I_{3YY} + \frac{(\lambda^-)^3 t}{12} \quad (37)$$

$$K^2 = \frac{I_2^-}{A_2^-} \quad (38)$$

```
      REM CHARACTERISTICS, AREA, LOCATION NA, MOMENT OF INERTIA
      REM CALCULATION OF EFFECTIVE AREAS
INSBP CLA SCANT+3,2                      A3
      TMI INDCA+10                       if THERE IS NO BEAM, SKIP
      FAD TEMP                           λt
      STO TEMP+4                         A2 = A3 + λt    (28)
      CLA SCANT+3,2                      A3
      FAD TEMP+2                         λ⁻t
      STO TEMP+5                         A2⁻ = A3 + λ⁻t   (29)
      REM CALCULATION OF EFFECTIVE I (YY)
      LDQ ASIDE+4                        b³/12
      FMP LOC+7,1                        t
      FAD SCANT+6,2                      I3yy
      STO TEMP+8                         I2yy = I3yy + b³t/12   (36)
      CLA TEMP+7                         (λ⁻)³t/12
      FAD SCANT+6,2                      I3yy
      STO TEMP+9                         I2yy⁻ = I3yy + (λ⁻)³t/12   (37)
      REM CALCULATION OF NEUTRAL AXES
      CLA SCANT+9,2                      d
      FSB SCANT+4,2                      c3'
      FAD TEMP+6                         ½t
      STO TEMP+20                        d - c3' + t/2
      FDP TEMP+4                         A2
      FMP TEMP                           λt
      FAD SCANT+4,2                      c3'
      STO TEMP+10                        c2' = (λt/A2)(d - c3' + t/2) + c3'   (30)
      CLA TEMP+20                        d - c3' + t/2
      FDP TEMP+5                         A2⁻

                              82   82
```

FMP TEMP+2	$\lambda^{-} t$
FAD SCANT+4,2	c_3'
STO TEMP+11	$c_2'^{-} = \frac{\lambda^{-} t}{A_2^{-}}\left(d - c_3' + \frac{t}{2}\right) + c_3'$ (31)
REM CALCULATION OF EFFECTIVE MOMENTS OF INERTIA	
FSB SCANT+4,2	c_3'
STO TEMP+15	$c_2'^{-} - c_3'$
LDQ TEMP+15	$c_2'^{-} - c_3'$
FMP TEMP+15	$c_2'^{-} - c_3'$
STO TEMP+15	$(c_2'^{-} - c_3')^2$
LDQ TEMP+15	$(c_2'^{-} - c_3')^2$
FMP SCANT+3,2	A_3
FAD SCANT+5,2	I_3
STO TEMP+15	$I_3 + A_3 (c_2'^{-} - c_3')^2$
CLA TEMP+10	c_2'
FSB SCANT+4,2	c_3'
STO TEMP+14	$c_2' - c_3'$
LDQ TEMP+14	$c_2' - c_3'$
FMP TEMP+14	$c_2' - c_3'$
STO TEMP+14	$(c_2' - c_3')^2$
LDQ TEMP+14	$(c_2' - c_3')^2$
FMP SCANT+3,2	A_3
FAD SCANT+5,2	I_3
STO TEMP+14	$I_3 + A_3 (c_2' - c_3')^2$
CLA SCANT+9,2	d
FAD LOC+7,1	t
STO TEMP+16	$d + t$
FSB TEMP+10	c_2'
STO TEMP+12	$c_2 = d + t - c_2'$ (32)

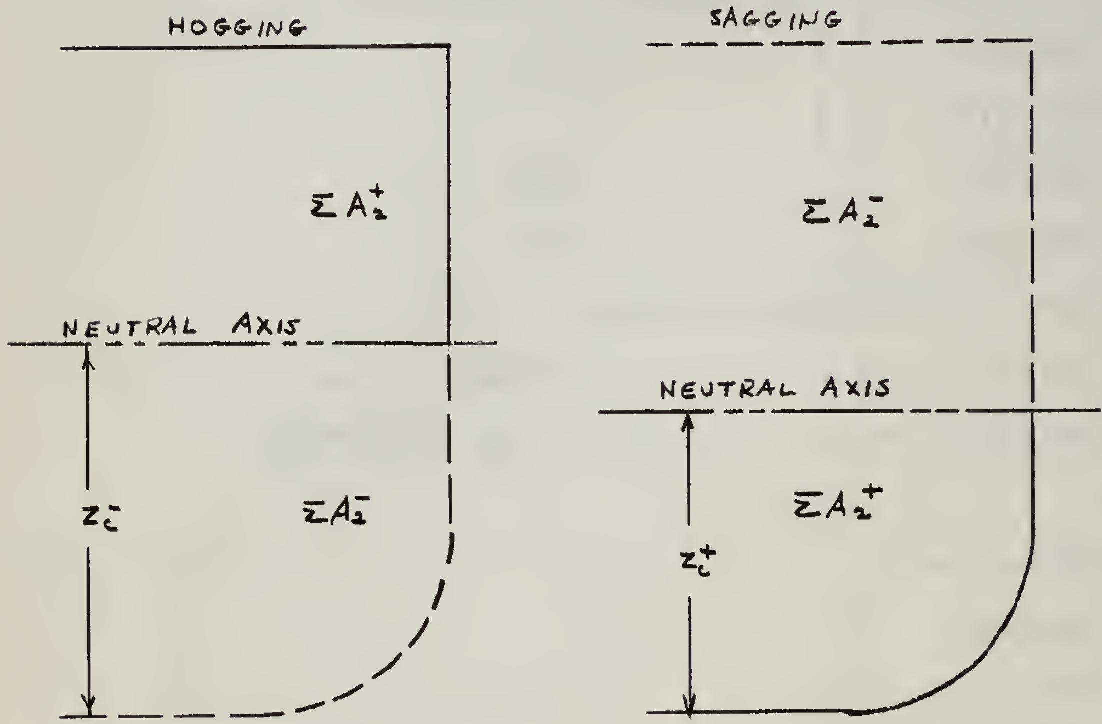
CLA TEMP+16	$d+t$
FSB TEMP+11	$c_2'^-$
STO TEMP+13	$c_2^- = d' + t - c_2'^-$ (33)
FSB TEMP+6	$t/2$
STO TEMP+16	$c_2^- - t/2$
LDQ TEMP+16	$c_2^- - t/2$
FMP TEMP+16	$c_2^- - t/2$
STO TEMP+16	$(c_2^- - t/2)^2$
LDQ TEMP+16	$(c_2^- - t/2)^2$
FMP TEMP+2	$\lambda^- t$
FAD TEMP+3	$\lambda^- t^3/12$
FAD TEMP+15	$I_3 + A_3(c_2'^- - c_3')^2$
STO TEMP+15	$I_2^- = I_3 + A_3(c_2'^- - c_3')^2 + \frac{\lambda^- t^3}{12} + \lambda^- t(c_2^- - \frac{t}{2})^2$ (35)
CLA TEMP+12	c_2
FSB TEMP+6	$t/2$
STO TEMP+16	$c_2 - t/2$
LDQ TEMP+16	$c_2 - t/2$
FMP TEMP+16	$c_2 - t/2$
STO TEMP+16	$(c_2 - t/2)^2$
LDQ TEMP+16	$(c_2 - t/2)^2$
FMP TEMP	λt
FAD TEMP+1	$\lambda t^3/12$
FAD TEMP+14	$I_3 + A_3(c_2' - c_3')^2$
STO TEMP+14	$I_2 = I_3 + A_3(c_2' - c_3')^2 + \frac{\lambda t^3}{12} + \lambda t(c_2 - t/2)^2$ (34)
REM CALCULATION OF RADIUS OF GYRATION	
CLA TEMP+15	I_2^-
FDP TEMP+5	A_2^-
STQ TEMP+16	$K^2 = I_2^-/A_2^-$ (38)

79 79

```
      CLA TEMP+16                  K^2
      TSX SQRT,4
      HTR                          ERROR STOP
      STO TEMP+16                  K
      REM CALCULATION OF SPAN/RADIUS OF GYRATION
      CLA INPUT+5                  a
      FDP TEMP+16                  K
      STQ TEMP+16                  a/K
      CLA TEMP+16                  a/K
      REM TEST OF SELECTED SCANTLING
      CAS LOC+6,1                  COMPARE a/K WITH a/K (MAX)
INDCA TXI INSBP,2            (-10) if a/K > a/K (MAX)
      NOP
      CLA TEMP+14                  I2
      FDP TEMP+12                  c2
      CLA LOC+12,1                 I2/c2 (MIN)
      TLQ INDCA                    IF I2/c2 < I2/c2 (MIN)
      CLA TEMP+14                  I2
      FDP TEMP+10                  c2'
      CLA LOC+13,1                 I2/c2' (MIN)
      TLQ INDCA                    if I2/c1' < I2/c1 (MIN)
      REM STORING DESCRIPTION AND PROPERTIES OF SELECTED SCANTLING
      CLA SCANT,2                  BEAM DESIGNATION
      STO LOC+3,1                    "        "
      CLA SCANT+1,2                  "        "
      STO LOC+4,1                    "        "
      CLA SCANT+2,2                  "        "
      STO LOC+5,1                    "        "
```

FIGURE 9

Effective Areas for determining Locations of Neutral Axes



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```
      LDQ LOC+7,1                           t
      FMP ASIDE+2                           b
      FAD SCANT+3,2                         A3
      STO LOC+7,1                           A2+ = A3 + bt
      CLA TEMP+5                            A2-
      STO LOC+8,1                           A2-
      CLA TEMP+14                           I2
      STO LOC+9,1                           I2
      CLA TEMP+15                           I2-
      STO LOC+10,1                          I2-
      CLA TEMP+8                            I2yy
      STO LOC+11,1                          I2yy
      CLA TEMP+9                            I2-yy
      STO LOC+12,1                          I2-yy
INDBE TXI INSBO,1                (-32)
      REM LOCATION OF NEUTRAL AXES, ACCURACY TO HALF SCANT SPACE
      REM NEUTRAL AXIS FOR SHIP SAGGING
INSBQ LXD NIX,3                             RESET INDICES 1 AND 2
      STZ TEMP                              0.0
      STZ TEMP+1                            0.0
      STZ TEMP+2                            0.0
      STZ TEMP+3                            0.0
INSBR CLA LOC+1,1                           z
      TMI INSBT                             if z = -1, LEAVE LOOP
      CLA REMEM+2                           zc+
      FSB LOC+1,1                           z
      TMI INSBS                             if z > zc+, SKIP
      CLA TEMP                              Σ A
```


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84 8 48 4

```
       FAD LOC+7,1            A2+
       STO TEMP               ΣA
       LDQ LOC+7,1            A2+
       FMP LOC+1,1            z
       FAD TEMP+2             ΣAz
       STO TEMP+2             ΣAz
INDBF  TXI INSBR,1      (-32)
INSBS  CLA TEMP               ΣA
       FAD LOC+8,1            A2-
       STO TEMP               ΣA
       LDQ LOC+8,1            A2-
       FMP LOC+1,1            z
       FAD TEMP+2             ΣAz
       STO TEMP+2             ΣAz
       REM NEUTRAL AXIS FOR SHIP HOGGING
INDBG  TXI INSBR,1      (-32)
INSBT  LXD NIX,1              RESET INDEX 1
       CLA TEMP+2             ΣAz
       FDP TEMP               ΣA
       CLA REMEM+2            zc+ (PREVIOUS ESTIMATE)
       STO REMEM+6            zc+ (PREVIOUS ESTIMATE)
       STQ REMEM+2            zc+ (COMPUTED)
INSBY  CLA LOC+1,1            z
       TMI INSCA              IF z=-1, LEAVE LOOP
       CLA REMEM+3            zc-
       FSB LOC+1,1            z
       TMI INSBZ              IF z>zc-, SKIP
       CLA TEMP+1             ΣA
```


86 8 6 86

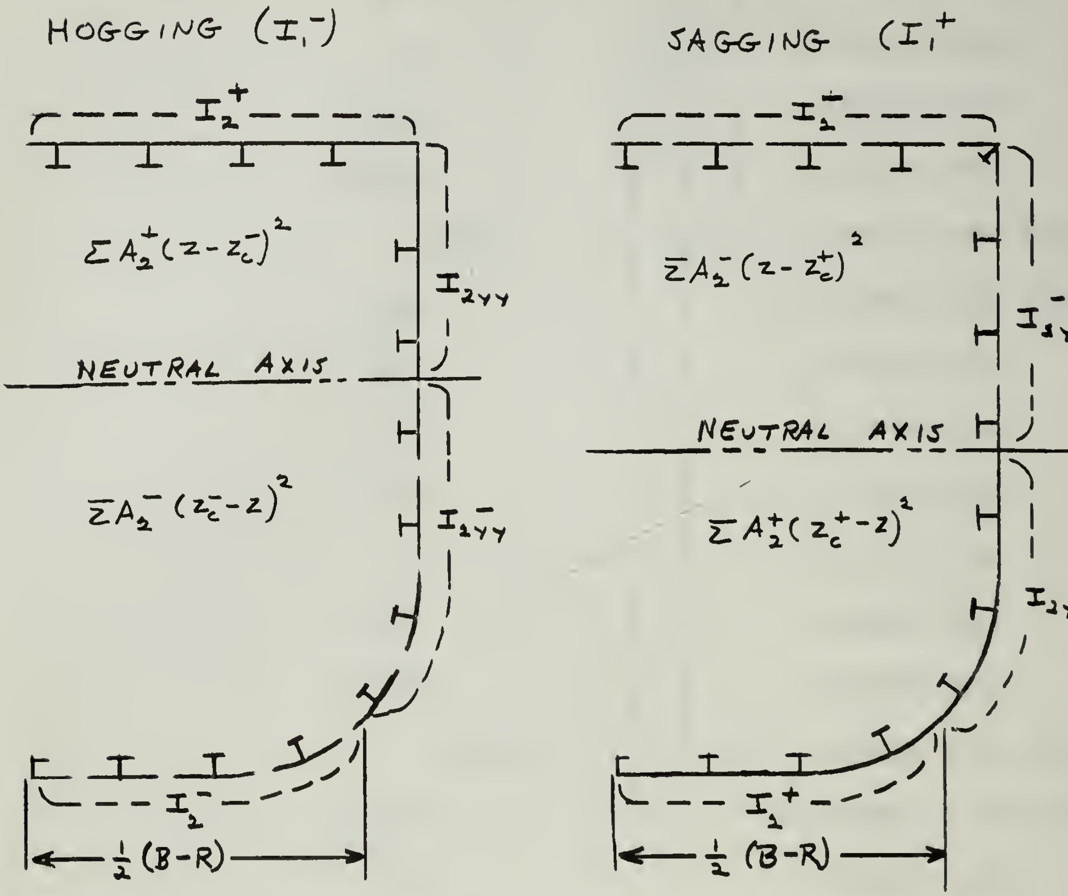
85 85 85

```
      FAD LOC+8,1           A2-
      STO TEMP+1            ΣA
      LDQ LOC+8,1           A2-
      FMP LOC+1,1           z
      FAD TEMP+3            ΣAz
      STO TEMP+3            ΣAz
INDBH TXI INSBY,1       (-32)
INSBZ CLA TEMP+1            ΣA
      FAD LOC+7,1           A2+
      STO TEMP+1            ΣA
      LDQ LOC+7,1           A2+
      FMP LOC+1,1           z
      FAD TEMP+3            ΣAz
      STO TEMP+3            ΣAz
INDBW TXI INSBY,1       (-32)
INSCA CLA TEMP+3            ΣAz
      FDP TEMP+1            ΣA
      CLA REMEM+3           zc- (PREVIOUS ESTIMATE)
      STO REMEM+7           zc- (PREVIOUS ESTIMATE)
      STQ REMEM+3           zc- (COMPUTED)
      LXD NIX,1             RESET INDEX 1
      STZ TEMP+2            0.0
      STZ TEMP+3            0.0
      REM MOM OF INERTIA FOR POSITIVE SHIP BENDING MOMENT
      REM EFFECTIVE AREAS TIMES DISTANCES TO NEUTRAL AXIS SQUARED
INSCF CLA LOC+1,1           z
      TMI INSCH             if z=-1, LEAVE LOOP
      CLA REMEM+2           zc+
```


88 88

FIGURE 10

Effective areas and moments of inertia for determining total effective moments of inertia



86 86

	FSB	LOC+1,1		z
	TMI	INSCG		if $z > z_c^+$, SKIP
	STO	TEMP		$z_c^+ - z$
	LDQ	TEMP		$z_c^+ - z$
	FMP	TEMP		$z_c^+ - z$
	STO	TEMP		$(z_c^+ - z)^2$
	LDQ	TEMP		$(z_c^+ - z)^2$
	FMP	LOC+7,1		A_i^+
	FAD	TEMP+2		$\Sigma A(\Delta z^2)$
	STO	TEMP+2		$\Sigma A(\Delta z^2)$
INDBI	TXI	INSCF,1	(-32)	
INSCG	CLA	LOC+1,1		z
	FSB	REMEM+2		z_c^+
	STO	TEMP		$z - z_c^+$
	LDQ	TEMP		$z - z_c^+$
	FMP	TEMP		$z - z_c^+$
	STO	TEMP		$(z - z_c^+)^2$
	LDQ	TEMP		$(z - z_c^+)^2$
	FMP	LOC+8,1		A_i^-
	FAD	TEMP+2		$\Sigma A(\Delta z^2)$
	STO	TEMP+2		$\Sigma A(\Delta z^2)$
INDBJ	TXI	INSCF,1	(-32)	
	REM	MOMENTS OF INERTIA ALONG THE BOTTOM OF HULL		
INSCH	LXD	NIX,1		RESET INDEX 1
INSCI	LDQ	ASIDE+7		$\frac{1}{2}(B-R)$
	CLA	LOC+2,1		Y
	TLQ	INSCJ		if $y > \frac{1}{2}(B-R)$, LEAVE LOOP
	CLA	LOC+9,1		I_i^+

89 89

88 88

Label	Operation	Address		Comment
	FAD	TEMP+2		$\Sigma A(\Delta z^2)+\Sigma I_2$
	STO	TEMP+2		$\Sigma A(\Delta z^2)+\Sigma I_2$
INDBK	TXI	INSCI,1	(-32)	
	REM	MOMENTS OF INERTIA ALONG SIDE OF HULL BELOW NEUTRAL AXIS		
INSCJ	CLA	LOC+1,1		z
	CAS	INPUT		COMPARE z WITH D
	NOP			
	TRA	INSCL		IF $z = D$, LEAVE LOOP
	CLA	REMEM+2		z_c^+
	FSB	LOC+1,1		z
	TMI	INSCK		IF $z > z_c^+$, SKIP
	CLA	LOC+11,1		I_{2yy}^+
	FAD	TEMP+2		$\Sigma A(\Delta z^2)+\Sigma I_2$
	STO	TEMP+2		$\Sigma A(\Delta z^2)+\Sigma I_2$
INDBL	TXI	INSCJ,1	(-32)	
	REM	MOMENTS OF INERTIA ALONG SIDE OF HULL ABOVE NEUTRAL AXIS		
INSCK	CLA	LOC+12,1		I_{2yy}^-
	FAD	TEMP+2		$\Sigma A(\Delta z^2)+\Sigma I_2$
	STO	TEMP+2		$\Sigma A(\Delta z^2)+\Sigma I_2$
INDBM	TXI	INSCJ,1	(-32)	
	REM	MOMENTS OF INERTIA ALONG THE DECK		
INSCL	CLA	LOC+1,1		z
	TMI	INSCM		if $z=-1$, LEAVE LOOP
	CLA	LOC+10,1		I_2^-
	FAD	TEMP+2		$\Sigma A(\Delta z^2)+\Sigma I_2$
	STO	TEMP+2		$\Sigma A(\Delta z^2)+\Sigma I_2$
INDBN	TXI	INSCL,1	(-32)	
INSCM	LXD	NIX,1		RESET INDEX 1

REM MOMENT OF INERTIA FOR NEGATIVE BENDING MOMENT

REM EFFECTIVE AREAS TIMES DISTANCES TO NEUTRAL AXIS SQUARED

INSCN	CLA	LOC+1,1		z
	TMI	INSCP		if $z=-1$, LEAVE LOOP
	CLA	REMEM+3		z_c^-
	FSB	LOC+1,1		z
	TMI	INSCO		if $z > z_c^-$, SKIP
	STO	TEMP+1		$z_c^- - z$
	LDQ	TEMP+1		$z_c^- - z$
	FMP	TEMP+1		$z_c^- - z$
	STO	TEMP+1		$(z_c^- - z)^2$
	LDQ	TEMP+1		$(z_c^- - z)^2$
	FMP	LOC+8,1		A_z^-
	FAD	TEMP+3		$\Sigma A(\Delta z^2)$
	STO	TEMP+3		$\Sigma A(\Delta z^2)$
INDBO	TXI	INSCN,1	(-32)	
INSCO	CLA	LOC+1,1		z
	FSB	REMEM+3		z_c^-
	STO	TEMP+1		$z - z_c^-$
	LDQ	TEMP+1		$z - z_c^-$
	FMP	TEMP+1		$z - z_c^-$
	STO	TEMP+1		$(z - z_c^-)^2$
	LDQ	TEMP+1		$(z - z_c^-)^2$
	FMP	LOC+7,1		A_z^+
	FAD	TEMP+3		$\Sigma A(\Delta z^2)$
	STO	TEMP+3		$\Sigma A(\Delta z^2)$
INDBP	TXI	INSCN,1	(-32)	

REM MOMENTS OF INERTIA ALONG THE BOTTOM OF HULL

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```
INSCP  LXD NIX,1                          RESET INDEX 1
INSCQ  LDQ ASIDE+7                        1/2 (B-R)
       CLA LOC+2,1                        Y
       TLQ INSCR                          if Y > 1/2 (B-R), LEAVE LOOP
       CLA LOC+10,1                       I2
       FAD TEMP+3                         ΣA(ΔZ²) + ΣI2
       STO TEMP+3                         ΣA(ΔZ²) + ΣI2
INDBQ  TXI INSCQ,1          (-32)
       REM MOMENTS OF INERTIA ALONG SIDE OF HULL BELOW NEUTRAL
                                                          AXIS
INSCR  CLA LOC+1,1                        Z
       CAS INPUT                          D
       NOP
       TRA INSCT                          if Z = D, LEAVE LOOP
       CLA REMEM+3                        Zc
       FSB LOC+1,1                        Z
       TMI INSCS                          if Z > Zc, SKIP
       CLA LOC+12,1                       I2YY
       FAD TEMP+3                         ΣA(ΔZ²) + ΣI2
       STO TEMP+3                         ΣA(ΔZ²) + ΣI2
INDBR  TXI INSCR,1          (-32)
       REM MOMENTS OF INERTIA ALONG SIDE OF HULL ABOVE NEUTRAL
                                                          AXIS
INSCS  CLA LOC+11,1                       I2YY+
       FAD TEMP+3                         ΣA(ΔZ²) + ΣI2
       STO TEMP+3                         ΣA(ΔZ²) + ΣI2
INDBS  TXI INSCR,1          (-32)
       REM MOMENTS OF INERTIA ALONG THE DECK
INSCT  CLA LOC+1,1                        Z
       TMI INSCU                          if Z = -1, LEAVE LOOP
```

92 92 91

```
                91      91
      CLA LOC+9,1                          I_2^+
      FAD TEMP+3                           ΣA(ΔZ²) + ΣI_2
      STO TEMP+3                           ΣA(ΔZ²) + ΣI_2
INDBT TXI INSCT,1              (-32)
INSCU LXD NIX,1                            RESET INDEX 1
      TSX M,4                              PRINT OUT I_1^+ AND I_1^- FOR
      PZE REMEM,0,REMEM+1                  CHECK OF INTERMEDIATE
                                           ESTIMATES OF MOM. OF INERTIA
      REM ACCURACY TEST FOR MOMENTS OF INERTIA
      CLA TEMP+3                           I_1^- (COMPUTED)
      FSB REMEM+1                          I_1^- (PREVIOUS ESTIMATE)
      FDP REMEM+1                          I_1^- (PREVIOUS ESTIMATE)
      STQ TEMP                             ΔI_1^- = (I_1^-(COMP) - I_1^-(P.E.)) / I_1^-(P.E)
      CLA TEMP                             ΔI_1^-
      SSP
      CAS INPUT+11                         COMPARE ΔI_1^- WITH ΔI_1 (MAX)
      NOP
      TRA BACK                             if ΔI_1^- ≥ ΔI_1^- (MAX)
      CLA TEMP+2                           I_1^+ (COMPUTED)
      FSB REMEM                            I_1^+ (PREVIOUS ESTIMATE)
      FDP REMEM                            I_1^+ (PREVIOUS ESTIMATE)
      STQ TEMP                             ΔI_1^+ = (I_1^+(COMP) - I_1^+(P.E.)) / I_1^+(P.E.)
      CLA TEMP                             ΔI_1^+
      SSP
      CAS INPUT+11                         COMPARE ΔI_1^+ WITH ΔI_1 (MAX)
      NOP
      TRA BACK                             if ΔI_1^+ ≥ ΔI_1 (MAX)
      TRA INSCV                            if ΔI_1^+ AND ΔI_1^- ARE < ΔI_1(MAX)
      REM ACCURACY CRITERIA FOR SHIP MOMENTS OF INERTIA HAS
                                                        FAILED,
                   94      95
```

Accuracy criterion for hull moment of inertia is given as a decimal fraction by INPUT+11 (ΔI). If this criterion is not met, the moments of inertia are altered by amounts given by CONST+27 and CONST+28 which are in this case 10% of the originally assumed moments of inertia.

The accuracy requirement for location of neutral axis is specified as one half the distance between longitudinals. If this criterion is not met, a mean between assumed and computed values of locations of neutral axes are used as the new assumptions.

The above has been found to be necessary in order to force the problem to a solution.

92 66

	REM	THE FOLLOWING INSTRUCTIONS MODIFY SHIPS MOMENT OF INERTIA	
BACK	CLA	REMEM+6	z_c^+ (PREV. EST.)
	FAD	REMEM+2	z_c^+ (COMPUTED)
	FDP	CONST+2	2.0
	STQ	REMEM+2	z_c^+ (NEW ESTIMATE)
	CLA	REMEM+7	z_c^- (PREV. EST.)
	FAD	REMEM+3	z_c^- (COMPUTED)
	FDP	CONST+2	2.0
	STQ	REMEM+3	z_c^- (NEW ESTIMATE)
	CLA	REMEM	I_1^+ (PREV. EST)
	CAS	TEMP+2	COMPARE WITH I_1^+ (COMPUTED)
	TRA	INSDC	if I_1^+ (P.E.) $>$ I_1^+ (COMP.)
	NOP		
	LDQ	CONST+28	1.10
	FMP	REMEM	I_1^+ (PREV EST)
	STO	REMEM	I_1^+ (NEW ESTIMATE)
	TRA	INSDD	
INSDC	LDQ	CONST+27	0.90
	FMP	REMEM	I_1^+ (PREV. EST.)
	STO	REMEM	I_1^+ (NEW ESTIMATE)
INSDD	CLA	REMEM+1	I_1^- (PREV. EST.)
	CAS	TEMP+3	COMPARE WITH I_1^- (COMPUTED)
	TRA	INSDE	if I_1^- (P.E.) $>$ I_1^- (COMP.)
	NOP		
	LDQ	CONST+28	1.10
	FMP	REMEM+1	I_1^- (PREV. EST.)
	STO	REMEM+1	I_1^- (NEW ESTIMATE)
	TRA	INSAS	RETURN TO RESIZE COMPONENTS UNDER NEW PRIMARY STRESS

95

94 6 6 92

INSDE	LDQ	CONST+27	0.90
	FMP	REMEM+1	I_1^- (PREV. EST.)
	STO	REMEM+1	I_1^- (NEW ESTIMATE)
	TRA	INSAS	RETURN TO RESIZE COMPONENTS UNDER NEW PRIMARY STRESS
	REM	ACCURACY TESTS FOR LOCATIONS OF NEUTRAL AXES	
INSCV	CLA	TEMP+3	I_1^- (COMPUTED)
	STO	REMEM+1	I_1^-
	CLA	TEMP+2	I_1^+ (COMPUTED)
	STO	REMEM	I_1^+
	CLA	REMEM+6	z_c^+ (PREV. EST.)
	FSB	REMEM+2	z_c^+ (COMPUTED)
	SSP		
	CAS	ASIDE+8	COMPARE Δz_c^+ WITH $b/2$
	NOP		
	TRA	INSAS	IF $\Delta z_c^+ > b/2$ RETURN
	CLA	REMEM+7	z_c^- (PREV. EST.)
	FSB	REMEM+3	z_c^- (COMPUTED)
	SSP		
	CAS	ASIDE+8	COMPARE Δz_c^- WITH $b/2$
	NOP		
	TRA	INSAS	IF $\Delta z_c^- > b/2$ RETURN
	REM	CALCULATION OF TOTAL CROSS SECTION AREA	
	STZ	TEMP	0.0
INSBX	CLA	LOC+1,1	z
	TMI	INSCW	IF $z = -1$, LEAVE LOOP
	CLA	LOC+7,1	A_2^+
	FAD	TEMP	ΣA
	STO	TEMP	ΣA

96 96

95 ↑ 95

```
INDBU TXI INSBX,1                    (-32)
      REM STORE AREA, NR SCANTLINGS AND FRAME SPACING
INSCW CLA TEMP                       A1+
      STO REMEM+12                   A1+
      CLA ASIDE                      n
      STO REMEM+13                   n
      CLA INPUT+5                    a
      STO REMEM+14                   a
      TSX L,4                        PRINT OUT A1+, n, a
      PZE REMEM+12,0,REMEM+14
      CLA TEMP+18                    CONTROL LOCATION
      TMI INSCZ+9                    if CONTROL LOCATION HAS -1.0
      REM COMPARE AREA WITH MINIMUM AREA THUS FAR OBTAINED
                                          AND STORE TH
      REM LESSER VALUE OF THE TWO AREAS AND ITS NR. SCANT.
                                          AND FR. SPAC
      CLA REMEM+12                   A1+
      CAS REMEM+5                    COMPARE A1+ WITH A1+(MIN)
      NOP
      TRA INSDB                      if A1+ ≥ A1+ (MIN)
      CLA REMEM+12                   A1+
      STO REMEM+5                    A1+ = A1+(min)
      CLA REMEM+13                   a
      STO REMEM+8                    a (for min A)
      CLA REMEM+14                   n
      STO REMEM+9                    n (for min A)
      REM RESET FOR NEXT NUMBER OF LONGITUDINALS
INSDB LXD NIX,3                      RESET INDICES 1 AND 2
      CLA ASIDE                      n
```

98 ↓

54

```
      FAD INPUT+9              Δn
      STO ASIDE                n
      CAS INPUT+10             COMPARE n WITH n_f
      TRA INSCY                if n > n_f
      NOP
INSCX LDQ ASIDE+1              b_0
      FMP INPUT+8              n_0
      FDP ASIDE                n
      STQ ASIDE+2              b = b_0 n_0/n
      TRA INSAA                RETURN FOR NEXT a,n
                                          COMBINATION
      REM RESET FOR NEXT FRAME SPACING
INSCY CLA INPUT+5              a
      FAD INPUT+6              Δa
      STO INPUT+5              a
      CAS INPUT+7              COMPARE a WITH a_f
      TRA INSCZ                if a > a_f
      NOP
      CLA INPUT+8              n_0
      STO ASIDE                n = n_0
      TRA INSCX                RETURN TO COMPUTE b
      REM RESET TO WORK OUT MINIMUM AREA COMBINATION
INSCZ CLA REMEM+8              a (min)
      STO INPUT+8              a_0 = a(min)
      STO INPUT+10             a = a(min)
      CLA REMEM+9              n (min)
      STO INPUT+5              n_0 = n (min)
      STO INPUT+7              n_f = n (min)
      CLA CONST                -1.0
```

```
                      54         96

       STO TEMP+18                    SET CONTROL LOCATION = -1.0
       TRA INSAA                      RETURN TO RECOMPUTE SCANTLINGS
                                      FOR MINIMUM AREA
       REM PRINT OUT ROUTINE TO PRINT OUT SCANTLING AND PLATE INFO
       CLA REMEM                      I1+ (in^4)
       FDP CONST+30                   144
       STQ REMEM                      I1+ (in^2 ft^2)
       CLA REMEM+1                    I1- (in^4)
       FDP CONST+30                   144
       STQ REMEM+1                    I1- (in^2 ft^2)
       LXD NIX,1                      RESET INDEX 1
       TSX M,4                        PRINT OUT MOMENTS OF INERTIA
       PZE REMEM,0,REMEM+1
       TSX Q,4                        PRINT OUT LOCATIONS OF NEUTRAL
                                                                AXES
       PZE REMEM+2,0,REMEM+3
INSDA  CLA LOC+1,1                    z
       TMI OUT                        if z=-1, LEAVE LOOP
       CAL CRANK                      THE FOLLOWING INSTRUCTIONS
       ACL ONE                        PERTAIN TO PRINTING OUT
       SLW ONE                        RESULTS OF COMPUTATIONS
       CAL CRANK
       ACL TWO
       SLW TWO
       CAL CRANK
       ACL THREE
       SLW THREE
       CAL CRANK
       ACL FOUR
       SLW FOUR

                      99          99
```

```
                                98 98
       TSX N,4                              PRINT OUT COORDINATES OF
ONE    PZE LOC-32,0,LOC-30                  SCANTLINGS
       TSX WOT,4                            PRINT OUT BEAM DESIGNATION
TWO    PZE LOC-29,0,LOC-27
       TSX 0,4                              PRINT OUT LENGTH/RADIUS OF
THREE  PZE LOC-26,0,LOC-26                  GYRATION (MAX)
       TSX P,4                              PRINT OUT PLATE CENTERLINE
FOUR   PZE LOC-16,0,LOC-13                  COORDINATES AND PLATE
                                            WEIGHT (LB/SQ FT)
INDBV  TXI INSDA,1            (-32)
OUT    HLT                                  END OF COMPUTATION
L      TRA BLOCK                            PRINT OUT STATEMENTS
       BCD 76H AREA=E15.8,6H    N=F6.1,6H    A=F6.1
M      TRA BLOCK
       BCD 812H INERTIA PL=E15.8,16H    INERTIA MIN=E15.8
Q      TRA BLOCK
       BCD 918H NEUTRAL AXIS SAG=F6.1,19H  NEUTRAL AXIS HOG=F6.1
N      TRA BLOCK
       BCD 810H LOCATION=F6.1,6H   Z=F6.1,6H     Y=F6.1
O      TRA BLOCK
       BCD 627H LENGTH/RADIUS OF GYRATION=F6.1
P      TRA BLOCK
       BCD 910H LOCATION=F6.1,4H  Z=F6.1,4H  Y=F6.1,5H  WT=F6.1
INPUT  BSS 30                               DEFINITION AND RESERVATION
ASIDE  BSS 15                               OF STORAGE LOCATIONS IN
REMEM  BSS 15                               COMPUTER MEMORY
LOC    BSS 5000
CONST  DEC -1.0,1.0,2.0,0.29289,-0.4292     CONSTANTS
       DEC 12.0,40000.,1.70,7.7855,-0.04
```

```
      DEC 0.29767,-0.02171546,1.5708,0.8660,0.50
      DEC 10414.,0.0127,30.,18.,324.0
      DEC 54.,9.6,-1.6,-0.88,16970.6,20.,1.5
      DEC 0.90,1.10,2240.0,144.0,0.0,0.0,0.0,0.0,0.0,
TEMP  BSS 40
NIX   PZE
CRANK PZE 32,0,32                     NUMBERS [illegible] TO [illegible]
HANDL PZE 0,0,15                      [illegible]
      PZE 0,0,31
      PZE 0,0,9
      PZE 0,0,2
00008 TRA INSDF                       ESCAPE FROM FLOATING-TRAP
INSDF SXD TEMP+17,1                   UNDERFLOW, ACCUMULATOR
      LXD 0,1                         IS SET TO 0.0 AND CONTROL
                                      IS RETURNED TO MAIN PRO-
                                      GRAM
      TNX INSDG,1,4                   IF UNDERFLOW HAS OCCURRED
                                       NUMBER < 10-38
      CAL 0
      HTR                             STOP IF OVERFLOW HAS
INSDG CAL 0                           OCCURRED NUMBER > 10+38
      STA INSDH
      PXD 0,0
      LXD TEMP+17,1
INSDH TRA 0 ------------------------> RETURN TO MAIN PROGRAM
      END START                       END OF PROGRAM
```

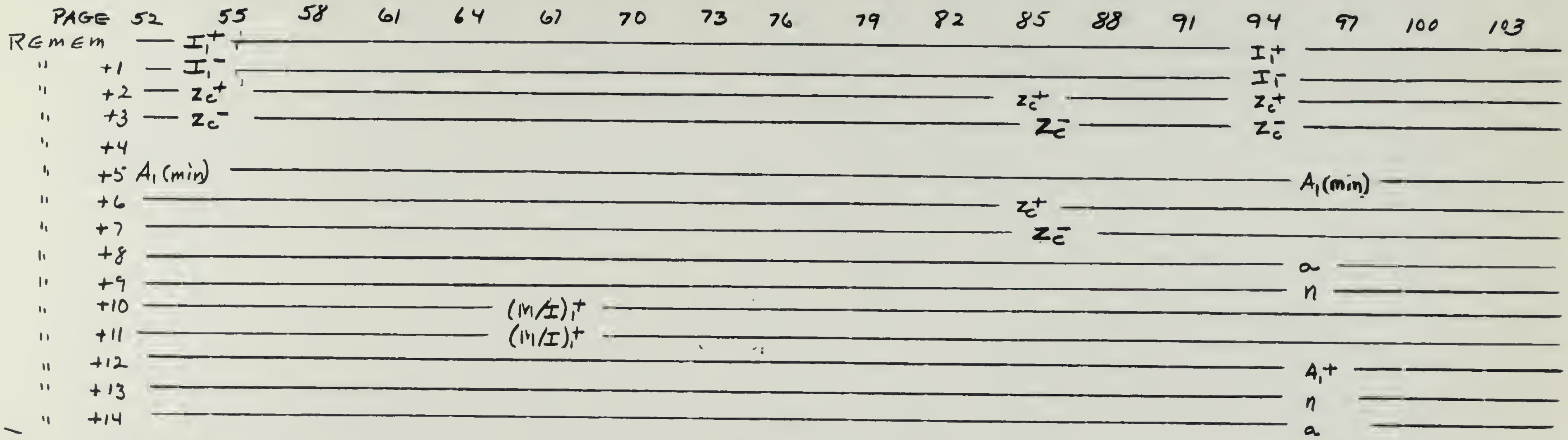
```
CST M885-721-PROGRAM
REM INPUT INFORMATION FOR PROGRAM M885
SAP M885-721-INPUT
LST OFF
ORG INPUT
DEC              (FT)  DEPTH
DEC              (FT)  BEAM
DEC              (FT)  BILGE RADIUS
DEC              (FT)  FULL LOAD DRAFT
DEC              (FT)  WAVE CREST HEIGHT ABOVE KEEL
DEC              (IN)  INITIAL FRAME SPACING
DEC              (IN)  INCREMENT OF FRAME SPACING
DEC              (IN)  FINAL FRAME SPACING
DEC                    INITIAL NUMBER OF LONGITUDINALS
DEC                    INCREMENT OF NUMBER OF LONGITUDINALS
DEC                    FINAL NUMBER OF LONGITUDINALS
DEC                    ACCURACY CRITERION FOR MOM. OF INERTIA
DEC              (FT-TONS) BENDING MOMENT SAGGING
DEC              (FT-TONS) BENDING MOMENT HOGGING
DEC              (FT)  MINIMUM HYDROSTATIC HEAD
DEC             (PSI)  ULTIMATE STRENGTH
DEC             (PSI)  YIELD STRENGTH IN TENSION
DEC             (PSI)  YIELD STRENGTH IN COMPRESSION
DEC             (PSI)  YOUNGS MODULUS
DEC             (PSI)  SECONDARY BENDING STRESS AT PLATE
END 0
PMD M885-721-PROGRAM                 POST MORTEM REQUEST
PMR LOC,LOC+1000,FLO,FPR
```

```
CLR

PAK

RIP M885-721-DATA-DAVIS

RIP M885-721-INPUT

RIP M885-721-PROGRAM

BGN M885-721-PROGRAM

XPM M885-721-PROGRAM

TER M885-721-PROGRAM
```

ADMINISTRATIVE INSTRUCTIONS

<u>Index of Addresses And Their Contents</u>

CONST	0	-1.0	SCANT	0	BEAM DESIGNATION	PLATE	0	lb/ft^2
"	1	1.0	"	1	" "	"	1	t
"	2	2.0	"	2	" "	"	2	t^2
"	3	0.29289	"	3	A_z			
"	4	-0.4292	"	4	c'_z			
"	5	12.0	"	5	I_z			
"	6	40000.0	"	6	I_{zyy}			
"	7	1.70	"	7	blank			
"	8	7.7855	"	8	blank			
"	9	-0.04	"	9	d			
"	10	0.29767						
"	11	-0.02171546						
"	12	1.5708	INPUT	0	D			
"	13	0.8660	"	1	B			
"	14	0.50	"	2	R			
"	15	10414.0	"	3	F			
"	16	0.0127	"	4	W			
"	17	30.0	"	5	a_o, a			
"	18	18.0	"	6	Δa			
"	19	324.0	"	7	a_f			
"	20	54.0	"	8	n_o			
"	21	9.6	"	9	Δn			
"	22	-1.6	"	10	n_f			
"	23	-0.88	"	11	ΔI			
"	24	16970	"	12	M_1^+			
"	25	20.0	"	13	M_1^-			
"	26	1.5	"	14	H_o			
"	27	0.90	"	15	σ_{ult}			
"	28	1.10	"	16	σ_{yp}^+			
"	29	2240.0	"	17	σ_{yp}^-			
"	30	144.0	"	18	E			
"	31	5.0	"	19	σ_z			


PAGE 52 55 58 61 64 67 70 73 76 79 82 85 88 91 94 97 100 103
REMEM
+1
+2
+3
+4
+5
+6
+7
+8
+9
+10
+11
+12
+13
+14
I_1^+
I_1^-
z_c^+
z_c^-
A_1(min)
$(M/I)_1^+$
$(M/I)_1^+$
α
n
A_1^+
n
α

PAGE:	52	55	58	61	64	67	70	73	76	79	82	85	88	91	94	97	100	103
TEMP				θ		t_{min}			λt			ΣA		$\Delta I_1^{\pm}$	ΣdA			
" +1				$\Delta\theta$					$\lambda t^3/12$			$\bar{\Sigma} A$						
" +2				$\sin\theta$					$\lambda^- t$			ΣAz	ΣdI_1^+					
" +3				$\cos\theta$					$\lambda^- t^3/12$			ΣAz		ΣdI_1^-				
" +4										A_2								
" +5										A_2^-								
" +6									$t/2$									
" +7									$(\lambda^-)^3 t/12$									
" +8										I_{2yy}								
" +9										I_{2yy}^-								
" +10										c_1'								
" +11										$c_2'^-$								
" +12										c_2								
" +13											c_2^-							
" +14											I_2							
" +15											I_2^-							
" +16											K^2 K							
" +17																		
" +18	+1.0															-1.0		
" +19																		
" +20										$d-c_3'+t/2$								
ASIDE	κ_0															n		
" +1	b_0																	
" +2	b_0															b		
" +3		b^2																
" +4		$b^3/12$																
" +5	$\frac{1}{2}B$																	
" +6																		
" +7	$\frac{1}{2}(B-R)$																	
" +8	$\frac{1}{2}b_0$	$b/2$																
" +9	$\frac{1}{2}B-R$																	
" +10		$\lambda^- A$																
" +11		λ																

LOC	PAGE:	52	55	58	61	64	67	70	73	76	79	82	85	88	91	94	97	100	103
LOC				C															
"	+1			Z															
"	+2			Y															
"	+3											BEAM DESIGNATION							
"	+4											BEAM DESIGNATION							
"	+5											BEAM DESIGNATION							
"	+6									a/K									
"	+7							t					A_2^+						
"	+8						σ_1^+						A_2^-						
"	+9						σ_1^-						I_2						
"	+10								M_2				I_2^-						
"	+11												I_{2YY}						
"	+12									I_2/c_2			$\overline{I_{2YY}}$						
"	+13									I_2/c_2'									
"	+14								X^-										
"	+15						H												
"	+16			C															
"	+17			Z															
"	+18			Y															
"	+19							PLATE DESIGNATION											
"	+20							t											
"	+21							t^2											
"	+22																		
"	+23																		
"	+24						σ_1^+												
"	+25						σ_1^-												
"	+26							σ_3											
"	+27																		
"	+28																		
"	+29																		
"	+30																		
"	+31						H												

FLOW DIAGRAM FOR SELECTING SCANTLINGS AND PLATING

constant geometrical parameters
$\frac{1}{2}B$, $\frac{1}{2}B-R$, $\frac{1}{2}(B-R)$, set A_1 (min),
set control location #1 = 1.0

initial longitudinal spacing
$\frac{1}{2}b$, b_o, b, n_o

first estimates of locations of neutral axes and moments of inertia
I_1^+, I_1^-, z_c^+, z_c^-

effective width λ^-

parameters of longitudinal spacing
b^2, $b^3/12$, $b/2$

effective breadth λ

numbering of locations
$c = 0.1, 2, \ldots, n$
is $c > n$? — NO

assign coordinates (-1,-1) to
$c = n+1$, $n+2$

coordinates along the bottom
is $y > \frac{1}{2}B-R$? — NO

coordinates along turn of bilge
is $\theta > \frac{1}{2}\pi$? — NO

coordinates along side of hull
is $z > D$? — NO

coordinates along deck
is $y < 0$? — NO

hydrostatic head
is $z < 0$? — NO

I

ship bending stress factors

(M_1^+/I_1^+), (M_1^-/I_1^-)

tensile stresses due to positive ship bending moment

is $z > z_c^+$? — NO

compressive stresses due to positive ship bending moment

is $z < 0$? — NO

compressive stresses due to negative ship bending moment

is $z > z_c^-$? — NO

tensile stresses due to negative ship bending moment

is $z < 0$? — NO

minimum thickness to withstand buckling

select thickness of plate

is t (available) > t (min.)? —NO→ (incr. t (avail))

stress schedules

are yield stresses exceeded? —YES→ (incr t (avail))

store plate information

is $z < 0$? — NO

secondary bending moments

is $z < 0$? — NO

required section moduli

radii of gyration (BUSHIP'S & Moncrieff)

is $z < 0$? — NO

plate parameters for selection of scantlings

t, $\frac{1}{2}t$, λt, $\lambda t^3/12$, $\bar{\lambda} t$, $\bar{\lambda} t^3/12$

III II I

[illegible]

III II I

conversion of beam characteristics to
beam plate characteristics

a/k, I/c, I/c'

are these characteristics
adequate? —— NO ——> select next beam

store beam and beam-plate information
is $z < 0$? —— NO

neutral axis due pos. ship bending moment

add up total area
is $z > z_c^+$? —— NO

add up effective area
is $z < 0$? —— NO

neutral axis due neg. ship bending moment

add up effective area
is $z > z_c^-$? —— NO

add up total area
is $z < 0$? —— NO

exchange computed and assumed
locations of neutral axes after
computing locations of neutral axes

moment of inertia for positive ship
bending moment

add total area x (dist to N.A.)^2
is $z > z_c^+$? —— NO

add effective area x (dist to N.A.)^2
is $z < 0$? —— NO

add I_2^+
is $y > \frac{1}{2}(B-R)$ —— NO

II I

II I

add I^{+}_{1yy}
is $z > z_c^{+}$? — NO

add I^{-}_{1yy}
is $z = D$? — NO

add I^{-}_{1}
is $z < 0$? — NO

moment of inertia for negative ship bending moment

add effective area x (dist to N.A.)^2
is $z > z_c^{-}$? — NO

add total area x (dist to N.A.)^2
is $z < 0$? — NO

add I^{-}_{2}
is $y > \frac{1}{2}(B-R)$? — NO

add I^{-}_{2yy}
is $z > z_c^{-}$? — NO

add I^{+}_{2yy}
is $z = D$? — NO

add I^{+}_{2}
is $z < 0$? — NO

compute ΔI_1^{+}
is $\Delta I_1^{+} <$ specified ΔI — NO

compute ΔI_1^{-}
is $\Delta I_1^{-} <$ specified ΔI → YES

increase or decrease I_1^{+} and I_1^{-} by 10%,
alter locations of neutral axes
and return to try again

II I

II I

exchange assumed and computed moments of inertia
compute Δz_c^+
is $\Delta z_c^+ < \frac{1}{2}b$ NO

compute Δz_c^-
is $\Delta z_c^- < \frac{1}{2}b$ NO

add up total area
is $z < 0$? NO

store total area
is control location < 0? YES

compare new total area with previous
minimum area, store minimum A_1, a, n

reset n
is $n > n_f$? NO

reset a
is $a > a_f$? → NO → SET $n = n_0$

set n_0, n_f, a_0, a_f, for minimum total
area, set control location to -1.
return for last run through

print out answers
end of program

APPENDIX D

PROGRAM FOR DESIGNING THE WEB FRAME

[illegible]

[illegible]

```
        CST M885-721-DATA-DAVIS
        SAP M885-721-PROGRAM
        LST OFF
        PRG OFF
COMMON  SYN/25
MICMD1  SYN/121
 SQRT   SYN /356
 COS    SYN /423
 SIN    SYN /424
 BLOCK  SYN /520
 WOT    SYN /1376
        ORG /10570
 START  CLA HANDL
        COM
        STD INDAA
        STD INDAB
        STD INDAC
        STD INDAD
        STD INDAE
        STD INDAF
        STD INDAG
        STD INDAH
        STD INDAI
        STD INDAJ
        CLA HANDL+1
        COM
        STD INDBA
        STD INDBB
        STD INDBC
        STD INDBD
        STD INDBE
        STD INDBF
        STD INDBG
        STD INDBH
        STD INDBI
        STD INDBJ
        STD INDBK
        STD INDBL
        STD INDBM
        STD INDBN
        STD INDBO
        STD INDBP
        STD INDBQ
        STD INDBR
        STD INDBS
        STD INDBT
        STD INDBU
        STD INDBV
        STD INDBW
        STD INDEA
        STD INDEA
        STD INDEB
        STD INDEC
        STD INDED
        STD INDEE
        STD INDEF
```

THIS PROGRAM IS SIMILAR TO THE PRECEDING PROGRAM FROM THIS PAGE TO PAGE 130. ACCORDINGLY, NO COMMENTS ARE INCLUDED FOR THIS PART.

```
STD INDEG
STD INDEH
STD INDEI
STD INDEJ
STD INDEK
STD INDEL
STD INDEM
CLA HANDL+2
COM
STD INDCA
CLA HANDL+3
COM
STD INDDA
STD INDDB
STD INDDC
STD INDDD
CLA NIX
COM
STD INDFA
EFM
REM CONVERSION OF UNITS
LDQ INPUT
FMP CONST+5
STO INPUT
LDQ INPUT+1
FMP CONST+5
STO INPUT+1
LDQ INPUT+2
FMP CONST+5
STO INPUT+2
LDQ INPUT+3
FMP CONST+5
STO INPUT+3
LDQ INPUT+4
FMP CONST+5
STO INPUT+4
LDQ INPUT+12
FMP CONST+5
STO INPUT+12
LDQ INPUT+13
FMP CONST+5
STO INPUT+13
LDQ INPUT+14
FMP CONST+5
STO INPUT+14
LDQ INPUT+12
FMP CONST+29
STO INPUT+12
LDQ INPUT+13
FMP CONST+29
STO INPUT+13
REM CALCULATION OF CONSTANT GEOMETRICAL PARAMETERS
CLA INPUT+1
FDP CONST+2
STQ ASIDE+5
CLA ASIDE+5
```

```
       FSB INPUT+2
       STO ASIDE+9
       FAD ASIDE+5
       FDP CONST+2
       STQ ASIDE+7
       CLA INPUT+12
       STO REMEM+5
       CLA CONST+1
       STO TEMP+18
       REM CALCULATION OF INITIAL LONGITUDINAL SPACING
       LDQ INPUT+2
       FMP CONST+4
       FAD INPUT
       FAD INPUT+1
       FDP INPUT+8
       STQ ASIDE+8
       FMP CONST+2
       STO ASIDE+1
       STO ASIDE+2
       CLA INPUT+8
       STO ASIDE
       REM CALCULATION OF ESTIMATED MOMENTS OF INERTIA
       LDQ INPUT+12
       FMP INPUT
       FDP CONST+6
       STQ REMEM
       LDQ INPUT+13
       FMP INPUT
       FDP CONST+6
       STQ REMEM+1
       REM FIRST ESTIMATE OF LOCATION OF NEUTRAL AXES
       CLA INPUT
       FDP CONST+2
       STQ REMEM+2
       STQ REMEM+3
       REM CALCULATION OF EFFECTIVE WIDTH (KARMAN SECHLER)
       CLA INPUT+18
       FDP INPUT+17
       STQ TEMP
       CLA TEMP
       TSX SQRT,4
       HTR
       STO TEMP
       LDQ TEMP
       FMP CONST+7
       STO ASIDE+10
       REM CALCULATIONS OF PARAMETERS OF LONGITUDINAL SPACING
INSAA  LDQ ASIDE+2
       FMP ASIDE+2
       STO ASIDE+3
       FDP CONST+5
       FMP ASIDE+2
       STO ASIDE+4
       CLA ASIDE+2
       FDP CONST+2
       STQ ASIDE+8
```

```
       REM EFFECTIVE BREADTH (SCHADE,SNAME TRANS. 11-51)
       LDQ ASIDE+2
       STQ ASIDE+11
       FMP CONST+8
       LDQ INPUT+5
       TLQ INSAB
       TRA INSAC
INSAB  LDQ ASIDE+2
       FMP CONST+9
       STO TEMP
       LDQ INPUT+5
       FMP CONST+10
       FAD TEMP
       STO TEMP
       LDQ INPUT+5
       FMP INPUT+5
       FDP ASIDE+2
       FMP CONST+11
       FAD TEMP
       STO ASIDE+11
INSAC  LXD NIX,1
       REM NUMBERING OF LOCATIONS, KEEL IS LOCATION ZERO
       CLA NIX
INSAD  STO LOC,1
       FAD CONST+1
INDAA  TXI INSAE,1
INSAE  CAS ASIDE
       TRA INSAF
       NOP
       TRA INSAD
INSAF  CLA CONST
       REM COORDINATES OF TWO LOCATIONS BEYOND THE LAST PERTINENT
       REM LOCATION ARE SET AT MINUS ONE TO FACILITATE PROGRAMMING
       STO LOC+1,1
       STO LOC+2,1
       STO LOC+26,1
       STO LOC+27,1
       REM CALCULATION OF LOCATION COORDINATES
       REM COORDINATES ALONG BOTTOM
       LXD NIX,1
       CLA NIX
INSAG  STO LOC+2,1
       FAD ASIDE+8
       STZ LOC+1,1
       STZ LOC+17,1
INDAB  TXI INSAH,1
INSAH  CAS ASIDE+9
       TRA INSAI
       NOP
       TRA INSAG
       REM COORDINATES AT TURN OF BILGE
INSAI  FSB ASIDE+9
       FDP INPUT+2
       STQ TEMP
       CLA ASIDE+8
       FDP INPUT+2
```

```
      FSB INPUT+2
      STO ASIDE+9
      FAD ASIDE+5
      FDP CONST+2
      STQ ASIDE+7
      CLA INPUT+12
      STO REMEM+5
      CLA CONST+1
      STO TEMP+18
      REM CALCULATION OF INITIAL LONGITUDINAL SPACING
      LDQ INPUT+2
      FMP CONST+4
      FAD INPUT
      FAD INPUT+1
      FDP INPUT+8
      STQ ASIDE+8
      FMP CONST+2
      STO ASIDE+1
      STO ASIDE+2
      CLA INPUT+8
      STO ASIDE
      REM CALCULATION OF ESTIMATED MOMENTS OF INERTIA
      LDQ INPUT+12
      FMP INPUT
      FDP CONST+6
      STQ REMEM
      LDQ INPUT+13
      FMP INPUT
      FDP CONST+6
      STQ REMEM+1
      REM FIRST ESTIMATE OF LOCATION OF NEUTRAL AXES
      CLA INPUT
      FDP CONST+2
      STQ REMEM+2
      STQ REMEM+3
      REM CALCULATION OF EFFECTIVE WIDTH (KARMAN SECHLER)
      CLA INPUT+18
      FDP INPUT+17
      STQ TEMP
      CLA TEMP
      TSX SQRT,4
      HTR
      STO TEMP
      LDQ TEMP
      FMP CONST+7
      STO ASIDE+10
      REM CALCULATIONS OF PARAMETERS OF LONGITUDINAL SPACING
INSAA LDQ ASIDE+2
      FMP ASIDE+2
      STQ ASIDE+3
      FDP CONST+5
      FMP ASIDE+2
      STO ASIDE+4
      CLA ASIDE+2
      FDP CONST+2
      STQ ASIDE+8
```

```
       FMP CONST+2
       STO LOC+17,1
       CLA INPUT
       STO LOC+1,1
 INDAE TXI INSAN,1
       REM BEGINNING OF GENERAL PROGRAM
       REM CALCULATION OF MAX HYDROSTATIC HEAD EACH LOCATION
 INSAO LXD NIX,1
 INSAP CLA LOC+1,1
       TMI INSAS
       CLA INPUT+4
       FSB LOC+1,1
       STO LOC+16,1
       CLA INPUT+3
       FSB LOC+1,1
       STO TEMP+1
       LDQ TEMP+1
       FMP CONST+13
       STO TEMP+1
       LDQ LOC+2,1
       FMP CONST+14
       FAD TEMP+1
       STO TEMP+1
       CLA INPUT+14
       CAS LOC+16,1
       TRA INSAQ
       NOP
       CLA LOC+16,1
 INSAQ STO LOC+16,1
       CAS TEMP+1
       TRA INSAR
       NOP
       CLA TEMP+1
 INSAR STO LOC+15,1
 INDAF TXI INSAP,1
       REM CALCULATION OF SHIP (PRIMARY) BENDING STRESSES
 INSAS LXD NIX,1
       CLA INPUT+12
       FDP REMEM
       STQ REMEM+10
       CLA INPUT+13
       FDP REMEM+1
       STQ REMEM+11
       REM STRESSES DUE TO POSITIVE SHIP BENDING MOMENT
 INSAT CLA REMEM+2
       FSB LOC+1,1
       TMI INSAU
       STO TEMP
       LDQ TEMP
       FMP REMEM+10
       STO LOC+8,1
 INDAG TXI INSAT,1
 INSAU CLA LOC+1,1
       TMI INSAV
       FSB REMEM+2
       STO TEMP
```

```
      LDQ TEMP
      FMP REMEM+10
      STO LOC+9,1
INDAH TXI INSAU,1
      REM STRESSES DUE TO NEGATIVE SHIP BENDING MOMENT
INSAV LXD NIX,1
INSAW CLA REMEM+3
      FSB LOC+1,1
      TMI INSAX
      STO TEMP
      LDQ TEMP
      FMP REMEM+11
      STO LOC+9,1
INDAI TXI INSAW,1
INSAX CLA LOC+1,1
      TMI INSAY
      FSB REMEM+3
      STO TEMP
      LDQ TEMP
      FMP REMEM+11
      STO LOC+8,1
INDAJ TXI INSAX,1
      REM SELECTION OF HULL PLATING BRYAN BUCKLING CRITERIA
INSAY LXD NIX,3
INSAZ CLA LOC+26,1
      TMI INSBC
      CLA LOC+34,1
      TSX SQRT,4
      HTR
      FDP CONST+15
      FMP ASIDE+2
      STO TEMP
      REM SELECTION OF PLATING THICKNESS FROM STD STOCK
INSBA CLA PLATE,2
      TMI INDDC+2
      CLA TEMP
      CAS PLATE+1,2
INDDA TXI INSBA,2
      REM TERTIARY STRESS CALCULATION
      NOP
INSBB LDQ ASIDE+3
      FMP LOC+40,1
      FDP PLATE+2,2
      FMP CONST+16
      STO LOC+35,1
      STO LOC+85,1
      REM STRESS SCHEDULE BETWEEN LONGITUDINALS
      FAD LOC+33,1
      FAD INPUT+19
      CAS INPUT+16
INDDB TXI INSBB,2
      NOP
      CLA LOC+34,1
      FAD LOC+35,1
      FSB INPUT+19
      CAS INPUT+17
```

```
INDDC TXI INSBB,2
      NOP
      CLA PLATE,2
      STO LOC+28,1
      CLA PLATE+1,2
      STO LOC+29,1
      STO LOC+79,1
      CLA PLATE+2,2
      STO LOC+30,1
      LXD NIX,2
INDBA TXI INSAZ,1
INSBC LXD NIX,3
      REM PLATE THICKNESSES TO BE ASSOCIATED WITH SCANTLINGS
      LDQ LOC+29
      STQ LOC+7
      FMP ASIDE+10
      CAS ASIDE+2
      CLA ASIDE+2
      NOP
      STO LOC+14
INDBB TXI INSBD,1
INSBD CLA LOC+1,1
      TMI INSBF
      CLA LOC-21,1
      FAD LOC+29,1
      FDP CONST+2
      STQ LOC+7,1
      STQ LOC+57,1
      FMP ASIDE+10
      CAS ASIDE+2
      CLA ASIDE+2
      NOP
      STO LOC+14,1
      TRA INDBB
INSBF LXD NIX,1
      REM CALCULATION OF SECONDARY BENDING MOMENTS
      LDQ INPUT+5
      FMP INPUT+5
      FDP CONST+19
      FMP ASIDE+2
      STO TEMP
INSBG CLA LOC+1,1
      TMI INSBH
      LDQ LOC+15,1
      FMP TEMP
      STO LOC+10,1
INDBC TXI INSBG,1
INSBH LXD NIX,1
      REM REQUIRED SECTION MODULI
INSBI CLA LOC+1,1
      TMI INSBN
      CLA INPUT+17
      FSB LOC+9,1
      FDP CONST+26
      STQ TEMP
      CLA INPUT+16
```

```
      FSB LOC+8,1
      FSB LOC+35,1
      CAS TEMP
      CLA TEMP
      NOP
      STO TEMP
      CLA LOC+10,1
      FDP TEMP
      STQ LOC+12,1
      CLA INPUT+16
      FSB LOC+8,1
      FDP CONST+26
      STQ TEMP
      CLA INPUT+17
      FSB LOC+9,1
      CAS TEMP
      CLA TEMP
      NOP
      STO TEMP
      CLA LOC+10,1
      FDP TEMP
      STQ LOC+13,1
      REM SPAN/RADIUS OF GYRATION. BUSHIPS CRITERION
      CLA LOC+1,1
      FDP INPUT
      FMP CONST+25
      FAD CONST+17
      STO LOC+6,1
      REM SPAN/RADIUS OF GYRATION, MONCRIEFF  FACTOR OF SAFETY = 1.0
      CLA LOC+9,1
      FSB INPUT+19
      TMI INDBD
      LDQ LOC+9,1
      FMP CONST+22
      FAD INPUT+15
      TMI INDBD
      FDP LOC+9,1
      STQ TEMP
      LDQ LOC+9,1
      FMP CONST+23
      FAD INPUT+15
      STO TEMP+1
      CLA TEMP
      FDP TEMP+1
      STQ TEMP
      CLA TEMP
      TSX SQRT,4
      TRA INDBD
      STO TEMP
      LDQ TEMP
      FMP CONST+24
      REM COMPARISON  OF RADII  OF GYRATION8 THE LESSER VALUE IS USED
      CAS LOC+6,1
      CLA LOC+6,1
      NOP
INSBM STO LOC+6,1
```

```
INDBD TXI INSBI,1
      REM PLATE PARAMETERS FOR SELECTION OF SCANTLINGS
INSBN LXD NIX,3
INSBO CLA LOC+1,1
      TMI INSBQ
      LXD NIX,2
      CLA LOC+7,1
      FDP CONST+2
      STQ TEMP+6
      LDQ LOC+7,1
      FMP ASIDE+11
      STO TEMP
      LDQ TEMP
      FMP LOC+7,1
      FDP CONST+5
      FMP LOC+7,1
      STO TEMP+1
      LDQ LOC+14,1
      FMP LOC+7,1
      STO TEMP+2
      FDP CONST+5
      FMP LOC+14,1
      STO TEMP+7
      LDQ TEMP+7
      FMP LOC+14,1
      STO TEMP+7
      CLA TEMP+1
      FDP ASIDE+11
      FMP LOC+14,1
      STO TEMP+3
      REM CONVERSION OF BEAM CHARACTERISTICS TO BEAM PLATE
      REM CHARACTERISTICS, AREA, LOCATION NA, MOMENT OF INERTIA
      REM CALCULATION OF EFFECTIVE AREAS
INSBP CLA SCANT+3,2
      TMI INDCA+10
      FAD TEMP
      STO TEMP+4
      CLA SCANT+3,2
      FAD TEMP+2
      STO TEMP+5
      REM CALCULATION OF EFFECTIVE I (YY)
      LDQ ASIDE+4
      FMP LOC+7,1
      FAD SCANT+6,2
      STO TEMP+8
      CLA TEMP+7
      FAD SCANT+6,2
      STO TEMP+9
      REM CALCULATIO  OF NEUTRAL AXES
      CLA SCANT+9,2
      FSB SCANT+4,2
      FAD TEMP+6
      STO TEMP+20
      FDP TEMP+4
      FMP TEMP
      FAD SCANT+4,2
```

```
STO TEMP+10
CLA TEMP+20
FDP TEMP+5
FMP TEMP+2
FAD SCANT+4,2
STO TEMP+11
REM  CALCULATION OF EFFECTIVE MOMENTS OF INERTIA
FSB SCANT+4,2
STO TEMP+15
LDQ TEMP+15
FMP TEMP+15
STO TEMP+15
LDQ TEMP+15
FMP SCANT+3,2
FAD SCANT+5,2
STO TEMP+15
CLA TEMP+10
FSB SCANT+4,2
STO TEMP+14
LDQ TEMP+14
FMP TEMP+14
STO TEMP+14
LDQ TEMP+14
FMP SCANT+3,2
FAD SCANT+5,2
STO TEMP+14
CLA SCANT+9,2
FAD LOC+7,1
STO TEMP+16
FSB TEMP+10
STO TEMP+12
CLA TEMP+16
FSB TEMP+11
STO TEMP+13
FSB TEMP+6
STO TEMP+16
LDQ TEMP+16
FMP TEMP+16
STO TEMP+16
LDQ TEMP+16
FMP TEMP+2
FAD TEMP+3
FAD TEMP+15
STO TEMP+15
CLA TEMP+12
FSB TEMP+6
STO TEMP+16
LDQ TEMP+16
FMP TEMP+16
STO TEMP+16
LDQ TEMP+16
FMP TEMP
FAD TEMP+1
FAD TEMP+14
STO TEMP+14
REM CALCULATION OF RADIUS OF GYRATION
```

```
       CLA TEMP+15
       FDP TEMP+5
       STQ TEMP+16
       CLA TEMP+16
       TSX SQRT,4
       HTR
       STO TEMP+16
       REM CALCULATION OF SPAN/RADIUS OF GYRATION
       CLA INPUT+5
       FDP TEMP+16
       STQ TEMP+16
       CLA TEMP+16
       REM TEST OF SELECTED SCANTLING
       CAS LOC+6,1
INDCA  TXI INSBP,2
       NOP
       CLA TEMP+14
       FDP TEMP+12
       CLA LOC+12,1
       TLQ INDCA
       CLA TEMP+14
       FDP TEMP+10
       CLA LOC+13,1
       TLQ INDCA
       REM STORING DESCRIPTION AND PROPERTIES OF SELECEED SCANTLING
       CLA SCANT,2
       STO LOC+3,1
       CLA SCANT+1,2
       STO LOC+4,1
       CLA SCANT+2,2
       STO LOC+5,1
       LDQ LOC+7,1
       FMP ASIDE+2
       FAD SCANT+3,2
       STO LOC+11,1
       CLA TEMP+5
       STO LOC+20,1
       CLA TEMP+14
       STO LOC+21,1
       CLA TEMP+15
       STO LOC+22,1
       CLA TEMP+8
       STO LOC+23,1
       CLA TEMP+9
       STO LOC+24,1
INDBE  TXI INSBO,1
       REM LOCATION OF NEUTRAL AXES, ACCURACY TO HALF SCANT SPACE
       REM NEUTRAL AXIS FOR SHIP SAGGING
INSBQ  LXD NIX,3
       STZ TEMP
       STZ TEMP+1
       STZ TEMP+2
       STZ TEMP+3
INSBR  CLA LOC+1,1
       TMI INSBT
       CLA REMEM+2
```

```
       FSB LOC+1,1
       TMI INSBS
       CLA TEMP
       FAD LOC+11,1
       STO TEMP
       LDQ LOC+11,1
       FMP LOC+1,1
       FAD TEMP+2
       STO TEMP+2
INDBF  TXI INSBR,1
INSBS  CLA TEMP
       FAD LOC+20,1
       STO TEMP
       LDQ LOC+20,1
       FMP LOC+1,1
       FAD TEMP+2
       STO TEMP+2
INDBG  TXI INSBR,1
INSBT  LXD NIX,1
       CLA TEMP+2
       FDP TEMP
       CLA REMEM+2
       STO REMEM+6
       STQ REMEM+2
       REM NEUTRAL AXIS FOR SHIP HOGGING
INSBY  CLA LOC+1,1
       TMI INSCA
       CLA REMEM+3
       FSB LOC+1,1
       TMI INSBZ
       CLA TEMP+1
       FAD LOC+20,1
       STO TEMP+1
       LDQ LOC+20,1
       FMP LOC+1,1
       FAD TEMP+3
       STO TEMP+3
INDBH  TXI INSBY,1
INSBZ  CLA TEMP+1
       FAD LOC+11,1
       STO TEMP+1
       LDQ LOC+11,1
       FMP LOC+1,1
       FAD TEMP+3
       STO TEMP+3
INDBW  TXI INSBY,1
INSCA  CLA TEMP+3
       FDP TEMP+1
       CLA REMEM+3
       STO REMEM+7
       STQ REMEM+3
       LXD NIX,1
       STZ TEMP+2
       STZ TEMP+3
       REM MOM OF INERTIA FOR POSITIVE SHIP BENDING MOMENT
       REM EFFECTIVE AREAS TIMES DISTANCES TO NEUTRAL AXIS SQUARED
```

```
INSCF CLA LOC+1,1
      TMI INSCH
      CLA REMEM+2
      FSB LOC+1,1
      TMI INSCG
      STO TEMP
      LDQ TEMP
      FMP TEMP
      STO TEMP
      LDQ TEMP
      FMP LOC+11,1
      FAD TEMP+2
      STO TEMP+2
INDBI TXI INSCF,1
INSCG CLA LOC+1,1
      FSB REMEM+2
      STO TEMP
      LDQ TEMP
      FMP TEMP
      STO TEMP
      LDQ TEMP
      FMP LOC+20,1
      FAD TEMP+2
      STO TEMP+2
INDBJ TXI INSCF,1
      REM MOMENTS OF INERTIA ALONG THE BOTTOM OF HULL
INSCH LXD NIX,1
INSCI LDQ ASIDE+7
      CLA LOC+2,1
      TLQ INSCJ
      CLA LOC+21,1
      FAD TEMP+2
      STO TEMP+2
INDBK TXI INSCI,1
      REM MOMENTS OF INERTIA ALONG SIDE OF HULL BELOW NEUTRAL AXIS
INSCJ CLA LOC+1,1
      CAS INPUT
      NOP
      TRA INSCL
      CLA REMEM+2
      FSB LOC+1,1
      TMI INSCK
      CLA LOC+23,1
      FAD TEMP+2
      STO TEMP+2
INDBL TXI INSCJ,1
      REM MOMENTS OF INERTIA ALONG SIDE OF HULL ABOVE NEUTRAL AXIS
INSCK CLA LOC+24,1
      FAD TEMP+2
      STO TEMP+2
INDBM TXI INSCJ,1
      REM MOMENTS OF INERTIA ALONG THE DECK
INSCL CLA LOC+1,1
      TMI INSCM
      CLA LOC+22,1
      FAD TEMP+2
```

```
       STO TEMP+2
 INDBN TXI INSCL,1
 INSCM LXD NIX,1
       REM MOMENT OF INERTIA FOR NEGATIVE BENDING MOMENT
       REM EFFECTIVE AREAS TIMES DISTANCES TO NEUTRAL AXIS SQUARED
 INSCN CLA LOC+1,1
       TMI INSCP
       CLA REMEM+3
       FSB LOC+1,1
       TMI INSCO
       STO TEMP+1
       LDQ TEMP+1
       FMP TEMP+1
       STO TEMP+1
       LDQ TEMP+1
       FMP LOC+20,1
       FAD TEMP+3
       STO TEMP+3
 INDBO TXI INSCN,1
 INSCO CLA LOC+1,1
       FSB REMEM+3
       STO TEMP+1
       LDQ TEMP+1
       FMP TEMP+1
       STO TEMP+1
       LDQ TEMP+1
       FMP LOC+11,1
       FAD TEMP+3
       STO TEMP+3
 INDBP TXI INSCN,1
       REM MOMENTS OF INERTIA ALONG THE BOTTOM OF HULL
 INSCP LXD NIX,1
 INSCQ LDQ ASIDE+7
       CLA LOC+2,1
       TLQ INSCR
       CLA LOC+22,1
       FAD TEMP+3
       STO TEMP+3
 INDBQ TXI INSCQ,1
       REM MOMENTS OF INERTIA ALONG SIDE OF HULL BELOW NEUTRAL AXIS
 INSCR CLA LOC+1,1
       CAS INPUT
       NOP
       TRA INSCT
       CLA REMEM+3
       FSB LOC+1,1
       TMI INSCS
       CLA LOC+24,1
       FAD TEMP+3
       STO TEMP+3
 INDBR TXI INSCR,1
       REM MOMENTS OF INERTIA ALONG SIDE OF HULL ABOVE NEUTRAL AXIS
 INSCS CLA LOC+23,1
       FAD TEMP+3
       STO TEMP+3
 INDBS TXI INSCR,1
```

```
      REM MOMENTS OF INERTIA ALONG THE DECK
INSCT CLA LOC+1,1
      TMI INSCU
      CLA LOC+21,1
      FAD TEMP+3
      STO TEMP+3
INDBT TXI INSCT,1
INSCU LXD NIX,1
      TSX M,4
      PZE REMEM,0,REMEM+1
      TSX Q,4
      PZE REMEM+2,0,REMEM+3
      REM ACCURACY TEST FOR MOMENTS OF INERTIA
      CLA TEMP+3
      FSB REMEM+1
      FDP REMEM+1
      STQ TEMP
      CLA TEMP
      SSP
      CAS INPUT+11
      NOP
      TRA BACK
      CLA TEMP+2
      FSB REMEM
      FDP REMEM
      STQ TEMP
      CLA TEMP
      SSP
      CAS INPUT+11
      NOP
      TRA BACK
      TRA INSCV
      REM ACCURA Y CRITERIA FOR SHIP MOMENTS OF INERTIA HAS FAILED,
      REM THE FOLLOWING INSTRUCTIONS MODIFY SHIPS MOMENT OF INERTIA
BACK  CLA REMEM+6
      FAD REMEM+2
      FDP CONST+2
      STQ REMEM+2
      CLA REMEM+7
      FAD REMEM+3
      FDP CONST+2
      STQ REMEM+3
      CLA REMEM
      CAS TEMP+2
      TRA INSDC
      NOP
      LDQ CONST+28
      FMP REMEM
      STO REMEM
      TRA INSDD
INSDC LDQ CONST+27
      FMP REMEM
      STO REMEM
INSDD CLA REMEM+1
      CAS TEMP+3
      TRA INSDE
```

```
       NOP
       LDQ CONST+28
       FMP REMEM+1
       STO REMEM+1
       TRA INSAS
INSDE  LDQ CONST+27
       FMP REMEM+1
       STO REMEM+1
       TRA INSAS
       REM ACCURACY TESTS FOR LOCATIONS OF NEUTRAL AXES
INSCV  CLA TEMP+3
       STO REMEM+1
       CLA TEMP+2
       STO REMEM
       CLA REMEM+6
       FSB REMEM+2
       SSP
       CAS ASIDE+8
       NOP
       TRA INSAS
       CLA REMEM+7
       FSB REMEM+3
       SSP
       CAS ASIDE+8
       NOP
       TRA INSAS
       REM CALCULATION OF TOTAL CROSS SECTION AREA
       STZ TEMP
INSBX  CLA LOC+1,1
       TMI INSCW
       CLA LOC+11,1
       FAD TEMP
       STO TEMP
INDBU  TXI INSBX,1
       REM STORE AREA, NR SCANTLINGS AND FRAME SPACING
INSCW  CLA TEMP
       STO REMEM+12
       CLA ASIDE
       STO REMEM+13
       CLA INPUT+5
       STO REMEM+14
       TSX L,4
       PZE REMEM+12,0,REMEM+14
       REM PRINT OUT ROUTINE TO PRINT OUT SCANTLING AND PLATE INFO
       CLA REMEM
       FDP CONST+30
       STQ REMEM
       CLA REMEM+1
       FDP CONST+30
       STQ REMEM+1
       LXD NIX,1
       TSX M,4
       PZE REMEM,0,REMEM+1
       TSX Q,4
       PZE REMEM+2,0,REMEM+3
INSDA  CLA LOC+1,1
```

```
       ACL ONE
       SLW ONE
       CAL CRANK
       ACL TWO
       SLW TWO
       CAL CRANK
       ACL THREE
       SLW THREE
       CAL CRANK
       ACL FOUR
       SLW FOUR
       TSX N,4
ONE    PZE LOC-50,0,LOC-48
       TSX WOT,4
TWO    PZE LOC-47,0,LOC-45
       TSX O,4
THREE  PZE LOC-44,0,LOC-44
       TSX P,4
FOUR   PZE LOC-25,0,LOC-22
INDBV  TXI INSDA,1

       REM FIRST AND SECOND MOMENTS OF AREAS

OUT    STZ TEMP                 SET TO ZERO
       STZ TEMP+1               SET TO ZERO
       STZ TEMP+2               SET TO ZERO
       STZ TEMP+3               SET TO ZERO
       LXD NIX,1                RESET INDEX 1
INSEA  CLA LOC+1,1              Z
       TMI INSEB                IF Z=-1 LEAVE LOOP
       CLA LOC+11,1             A2+
       FAD TEMP                 ΣA
       STO TEMP                 ΣA
       LDQ LOC+11,1             A2+
       FMP LOC+1,1              Z
       FAD TEMP+1               ΣAZ
       STO TEMP+1               ΣAZ
       LDQ LOC+1,1              Z
       FMP LOC+1,1              Z

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```
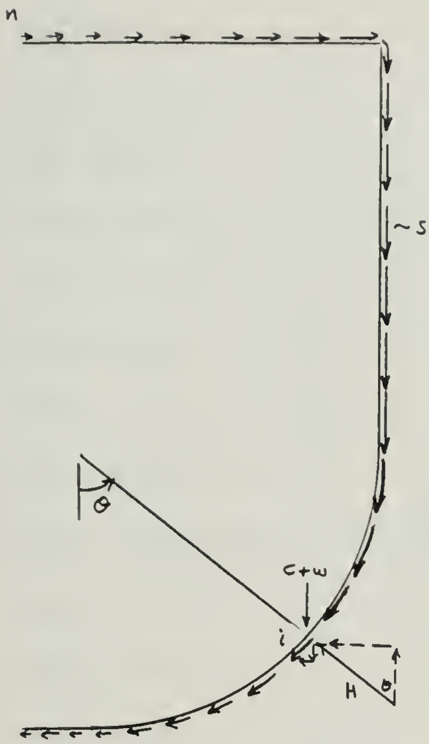

130 130

	STO	TEMP+4	z^2
	LDQ	LOC+11,1	A_2^+
	FMP	TEMP+4	z^2
	FAD	TEMP+2	$\Sigma A z^2$
	STO	TEMP+2	$\Sigma A z^2$
INDEA	TXI	INSEA,1	
INSEB	CLA	TEMP+1	$\Sigma A z$
	FDP	TEMP	ΣA
	STQ	TEMP+1	z_c
	FMP	TEMP+1	z_c
	STO	TEMP+4	z_c^2
	LDQ	TEMP	ΣA
	FMP	TEMP+4	z_c^2
	CHS		
	FAD	TEMP+2	$\Sigma A z^2$
	STO	TEMP+2	$I = \Sigma A z^2 - z_c^2 \Sigma A$
	LXD	NIX,1	RESET INDEX 1
INSEC	CLA	LOC+1,1	z
	TMI	INSED	IF $z = -1$, LEAVE LOOP
	FSB	TEMP+1	z_c
	CHS		
	STO	TEMP+5	$z_c - z$
	LDQ	LOC+11,1	A_2^+
	FMP	TEMP+5	$z_c - z$
	FAD	TEMP+3	$\Sigma A_2^+ (z_c - z)$
	STO	TEMP+3	$\Sigma A_2^+ (z_c - z)$
	STO	LOC+20,1	$Q_n = \sum_{n=0}^{n=n} A_{2n}^+ (z_c - z_n)$
INDEB	TXI	INSEC,1	

133.



$$V = \sum_{0}^{n} \left(H_i \cos \theta_i - (c+w)_i\right)$$

$$V = \sum_{0}^{n} S_i \sin \theta_i$$

$$S_i = \tau_i b t_i$$

$$\tau_i = \frac{VQ_i}{t_i I}$$

$$\therefore S_i = Q_i \left(\frac{Vb}{I}\right)$$

WHERE,

$$Q = \sum_{0}^{i} A_{2i}^{+} (z_c - z_i)$$

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```
INSED LXD NIX,1              RESET INDEX 1
INSEE CLA LOC+1,1            z
      TMI INDEC+1            IF z=-1, LEAVE LOOP
      CLA LOC+17,1           θ
      TSX SIN,4
      STO LOC+18,1           sin θ
      CLA LOC+17,1           θ
      TSX COS,4
      STO LOC+19,1           cos θ
INDEC TXI INSEE,1
      REM HYDROSTATIC AND INTERNAL LOAD COMPONENTS
      LXD NIX,3              RESET INDICES 1 AND 2
      CLA LOC+1,1            z
      TMI INDED+1            IF z=-1, LEAVE LOOP
      LDQ LOC+16,1           Hω
      FMP ASIDE+2            b
      STO LOC+16,1           Hω b
      LDQ LOC+16,1           bHω
      FMP INPUT+5            α
      STO LOC+16,1           H = αb Hω
      LDQ LOC+16,1           H
      FMP LOC+18,1           sin θ
      STO LOC+15,1           H sin θ
      LDQ LOC+16,1           H
      FMP LOC+19,1           cos θ
      FSB LOAD,2             c+ω
      STO LOC+16,1           H cos θ - (c+ω)
INDFA TXI INDED,2
```

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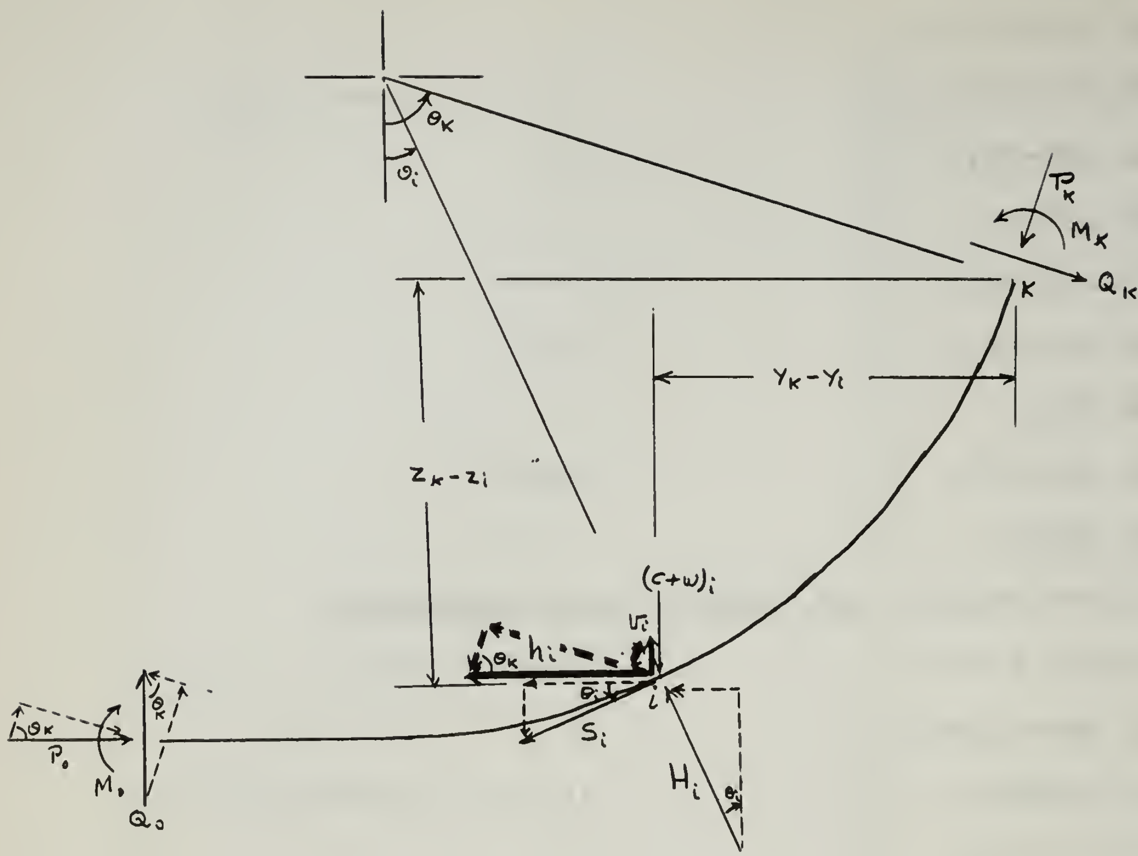

$$v_i = H_i \cos\theta_i - (c+w)_i - S_i \sin\theta_i$$

$$h_i = H_i \sin\theta_i + S_i \cos\theta_i$$

$$P_K = P_0 \cos\theta_K + Q_0 \sin\theta_K - \cos\theta_K \sum_{i=0}^{i=K} h_i + \sin\theta_K \sum_{i=0}^{i=K} v_i$$

$$Q_K = -P_0 \sin\theta_K + Q_0 \cos\theta_K + \sin\theta_K \sum_{i=0}^{i=K} h_i + \cos\theta_K \sum_{i=0}^{i=K} v_i$$

$$M_K = M_0 - P_0 Z_K + Q_0 Y_K + \sum_{i=0}^{i=K} h_i (Z_K - Z_i) + \sum_{i=0}^{i=K} v_i (Y_K - Y_i)$$

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INDED	TXI	INDEC+2,1	
	LXD	NIX,3	RESET INDICES 1 AND 2
	STZ	TEMP+4	SET TO ZERO
	STZ	TEMP+5	SET TO ZERO
	STZ	TEMP+6	SET TO ZERO
	STZ	TEMP+7	SET TO ZERO
	REM	SUMMATION OF EXTERNAL LOADS	
INSEF	CLA	LOC+1,1	z
	TMI	INDEE+1	IF $z = -1$, LEAVE LOOP
	CLA	LOC+15,1	$H \sin\theta$
	FAD	TEMP+4	$\Sigma H \sin\theta$
	STO	TEMP+4	$\Sigma H \sin\theta$
	STO	LOC+12,1	$\Sigma H \sin\theta$
	CLA	LOC+16,1	$H \cos\theta - (c+\omega)$
	FAD	TEMP+5	$\Sigma[H \cos\theta - (c+\omega)]$
	STO	TEMP+5	$\Sigma[H \cos\theta - (c+\omega)]$
	STO	LOC+13,1	$\Sigma[H \cos\theta - (c+\omega)]$
INDEE	TXI	INSEF,1	
	REM	SHEAR FORCE CALCULATIONS	
	LXD	NIX,1	RESET INDEX 1
	CLA	TEMP+5	$\Sigma[H \cos\theta - (c+\omega)] = V$
	FDP	TEMP+2	I
	FMP	ASIDE+2	b
	STO	REMEM+4	Vb/I
	CLA	LOC+1,1	z
	TMI	INDEF+1	IF $z = -1$, LEAVE LOOP
	LDQ	REMEM+4	Vb/I
	FMP	LOC+20,1	Q_n

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	STO	LOC+20,1	$S_n = \frac{bVQ_n}{I}$
	LDQ	LOC+19,1	$\cos\theta_n$
	FMP	LOC+20,1	S_n
	STO	LOC+21,1	$S_n \cos\theta_n$
	REM	TOTAL EXTERNAL FORCE COMPONENTS	
	FAD	TEMP+7	$\Sigma S_n \cos\theta_n$
	STO	TEMP+7	$\Sigma S_n \cos\theta_n$
	FAD	LOC+12,1	$\Sigma H \sin\theta$
	STO	LOC+12,1	$\Sigma [H \sin\theta + S\cos\theta]_n$
	CLA	LOC+21,1	$S_n \cos\theta_n$
	FAD	LOC+15,1	$H \sin\theta$
	STO	LOC+15,1	$H\sin\theta + S\cos\theta$
	LDQ	LOC+18,1	$\sin\theta$
	FMP	LOC+20,1	S_n
	STO	LOC+20,1	$S_n \sin\theta_n$
	FAD	TEMP+6	$\Sigma S_n \sin\theta_n$
	STO	TEMP+6	$\Sigma S_n \sin\theta_n$
	CHS		
	FAD	LOC+13,1	$\Sigma [H\cos\theta - (c+\omega)]$
	STO	LOC+13,1	$\Sigma [H\cos\theta - (c+\omega) - S\sin\theta]$
	CLA	LOC+16,1	$H\cos\theta - (c+\omega)$
	FSB	LOC+20,1	$S\sin\theta$
	STO	LOC+16,1	$H\cos\theta - (c+\omega) - S\sin\theta$
INDEF	TXI	INDEE+6,1	
	REM	TOTAL EXTERNAL MOMENT COMPONENTS	
	LXD	NIX,3	RESET INDICES 1 AND 2
INSEG	CLA	LOC+1,1	z
	TMI	INDEG+3	IF $z = -1$, LEAVE LOOP

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	STZ	LOC+3,1	SET TO ZERO
	STZ	LOC+4,1	SET TO ZERO
	STZ	LOC+5,1	SET TO ZERO
INSEH	CLA	LOC,2	c_i
	CAS	LOC,1	COMPARE c_i WITH c_K
	NOP		
	TRA	INDEG+1	IF $c_i \geqq c_K$ SKIP
	CLA	LOC+1,1	z_K
	FSB	LOC+1,2	z_i
	STO	TEMP	$z_K - z_i$
	LDQ	LOC+15,2	$H \sin\theta + S\cos\theta$
	FMP	TEMP	$z_K - z_i$
	FAD	LOC+5,1	$\Sigma[(H\sin\theta + S\cos\theta)_i (z_K - z_i)]$
	STO	LOC+5,1	$\Sigma[(H\sin\theta + S\cos\theta)(z_K - z)]_i$
	CLA	LOC+2,1	Y_K
	FSB	LOC+2,2	Y_i
	STO	TEMP	$Y_K - Y_i$
	LDQ	LOC+16,1	$H\cos\theta - (c+\omega) - S\sin\theta$
	FMP	TEMP	$Y_K - Y_i$
	FAD	LOC+5,1	$\Sigma[(H\cos\theta - (c+\omega) - S\sin\theta)(Y_K - Y)]_i + \Sigma[(H\sin\theta + S\cos\theta)(z_K - z)]_i = M_{EX}$
	STO	LOC+5,1	$\Sigma[(H\cos\theta - (c+\omega) - S\sin\theta)(Y_K - Y)]_i + \Sigma[(H\sin\theta + S\cos\theta)(z_K - z)]_i = M_{EX}$
	STO	LOC+24,1	$M = M_{EX}$
INDEG	TXI	INSEH,2	
	LXD	NIX,2	RESET INDEX 2
INDEH	TXI	INSEG,1	
	LXD	NIX,1	RESET INDEX 1
	CLA	LOC+1,1	z
	TMI	INDEI+1	IF Z = -1, LEAVE LOOP

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	LDQ	LOC+13,1	$\Sigma[H\cos\theta-(c+\omega)-S\sin\theta]$
	FMP	LOC+18,1	$\sin\theta$
	STO	LOC+3,1	$\sin\theta\,\Sigma[H\cos\theta-(c+\omega)-S\sin\theta]$
	LDQ	LOC+12,1	$\Sigma[H\sin\theta+S\cos\theta]$
	FMP	LOC+19,1	$\cos\theta$
	CHS		
	FAD	LOC+3,1	$P_{Ex}=\cos\theta\,\Sigma[H\sin\theta+S\cos\theta]$
	STO	LOC+3,1	$-\sin\theta\,\Sigma[H\cos\theta-(c+\omega)-S\sin\theta]$
	STO	LOC+22,1	$P=P_{Ex}$
	LDQ	LOC+13,1	$\Sigma[H\cos\theta-(c+\omega)-S\sin\theta]$
	FMP	LOC+19,1	$\cos\theta$
	STO	LOC+4,1	$\cos\theta\,\Sigma[H\cos\theta-(c+\omega)-S\sin\theta]$
	LDQ	LOC+12,1	$\Sigma[H\sin\theta+S\cos\theta]$
	FMP	LOC+18,1	$\sin\theta$
	FAD	LOC+4,1	$Q_{Ex}=\sin\theta\,\Sigma[H\sin\theta+S\cos\theta]$
	STO	LOC+4,1	$+\cos\theta\,\Sigma[H\cos\theta-(c+\omega)-S\sin\theta]$
	STO	LOC+23,1	$Q=Q_{Ex}$
INDEI	TXI	INDEH+2,1	
	STZ	REMEM+11	SET TO ZERO
	STZ	REMEM+12	SET TO ZERO
	STZ	REMEM+13	SET TO ZERO
	STZ	REMEM+14	SET TO ZERO
	LXD	NIX,3	RESET INDICES 1 AND 2
	REM	SIZING WEB DIMENSIONS	
INSEI	CLA	PLATE+1,2	t
	TMI	EXIT,4	IF $t=-1$ LEAVE PROGRAM
	LDQ	PLATE+1,2	t
	STQ	TEMP	$\tau=\tau_\omega$

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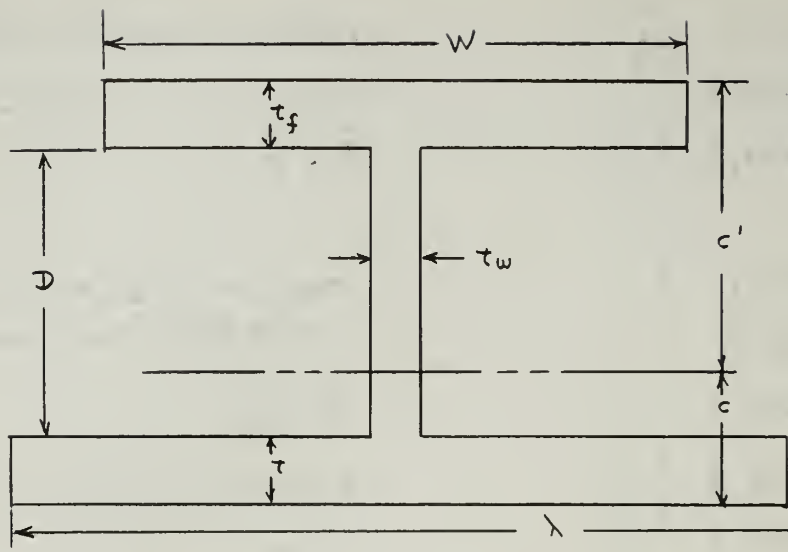

CRITERIA FOR SIZING COMPONENTS OF WEB FRAME

$$t_f = 1.5\, t_w$$

$$10 t_w \leq W \leq 30 t_w \qquad W \leq 2D$$

$$D \leq 60 t_w \qquad \lambda = 30 t$$

$$A = (\lambda - t_w)t + (D + t_f + t)t_w + (W - t_w)t_f$$

$$Q = (\lambda - t_w)\frac{t^2}{2} + (D + t_f + t)^2 \frac{t_w}{2} + (W - t_w)t_f\left(D + t + \frac{t_f}{2}\right)$$

$$I_0 = (\lambda - t_w)\frac{t^3}{3} + (D + t_f + t)^3 \frac{t_w}{3} + (W - t_w)t_f\left[\left(D + t + \frac{t_f}{2}\right)^2 + \frac{t_f^2}{12}\right]$$

$$c = \frac{Q}{A}$$

$$c' = (D + t + t_f) - c$$

	FMP CONST+26	1.5
	STO TEMP+1	$\tau_f = 1.5\tau_w$
	LDQ PLATE+1,2	τ_w
	FMP CONST+17	30
	STO TEMP+18	$30\tau_w$
	FDP CONST+14	0.5
	STQ TEMP+19	$60\tau_w$
	LDQ PLATE+1,2	τ_w
	FMP CONST+31	5
	STO TEMP+2	$D \geq 5\tau_w$
	FDP CONST+14	0.50
	STQ TEMP+3	$W \leq 2D \geq 10\tau_w$
	REM CALC OF AREA AND MOM OF INERTIA OF WEB	
INSEJ	LDQ LOC+7,1	τ
	FMP CONST+17	30 $\lambda = 30\tau$
	FSB PLATE+1,2	τ_w
	STO TEMP+4	$\lambda - \tau_w$
	LDQ TEMP+4	$\lambda - \tau_w$
	FMP LOC+7,1	τ
	STO TEMP+5	$(\lambda - \tau_w)\tau$
	LDQ TEMP+5	$(\lambda - \tau_w)\tau$
	FMP LOC+7,1	τ
	FDP CONST+2	2
	STQ TEMP+6	$(\lambda - \tau_w)\frac{\tau^2}{2}$
	FMP LOC+7,1	τ
	FDP CONST+26	1.5
	STQ TEMP+7	$(\lambda - \tau_w)\tau^3/3$
	CLA TEMP+2	D

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FAD LOC+7,1		t
FAD TEMP+1		t_f
STO TEMP+4		$D+t+t_f$
LDQ TEMP		t_w
FMP TEMP+4		$(D+t+t_f)$
STO TEMP+4		$(D+t+t_f)t_w$
FAD TEMP+5		$(\lambda-t_w)t$
STO TEMP+5		$(\lambda-t_w)t+(D+t+t_f)t_w$
CLA TEMP+4		$(D+t+t_f)t_w$
FDP CONST+2		2
FMP TEMP+4		$(D+t+t_f)t_w$
FDP TEMP		t_w
STQ TEMP+4		$(D+t+t_f)^2 t_w/2$
CLA TEMP+4		
FAD TEMP+6		$(\lambda-t_w)t^2/2$
STO TEMP+6		$(\lambda-t_w)t^2/2+(D+t+t_f)^2\frac{t_w}{2}$
CLA TEMP+4		$(D+t+t_f)t_w/2$
FDP CONST+26		1.5
FMP TEMP+4	FDP TEMP t_w	$(D+t+t_f)t_w$
	STQ TEMP+4	
FAD TEMP+7	CLA TEMP+4	$(\lambda-t_w)\frac{t^3}{3}$
STO TEMP+7		$(\lambda-t_w)\frac{t^3}{3}+(D+t+t_f)^3\frac{t_w}{3}$
CLA TEMP+3		W
FSB TEMP		t_w
STO TEMP+4		$W-t_w$
LDQ TEMP+4		$W-t_w$
FMP TEMP+1		t_f
STO TEMP+4		$(W-t_w)t_f$
FAD TEMP+5		$(\lambda-t_w)t+(D+t+t_f)t_w$
STO TEMP+5		$A=(\lambda-t_w)t+(D+t+t_f)t_w+(W-t_w)t_f$
CLA TEMP+1		t_f

FDP CONST+2	2
STQ TEMP+8	$t_f/2$
CLA TEMP+8	$t_f/2$
FAD LOC+7,1	τ
FAD TEMP+2	D
STO TEMP+8	$D+\tau+\frac{t_f}{2}$
LDQ TEMP+4	$(W-t_w)t_f$
FMP TEMP+8	$D+\tau+t_f/2$
FAD TEMP+6	$Q=(\lambda-t_w)t_f^2/2+(D+\tau+t_f)^2\frac{t_w}{2}+$
STO TEMP+6	$+(W-t_w)t_f\,(D+\tau+\frac{t_f}{2})$
LDQ TEMP+8	$D+\tau+t_f/2$
FMP TEMP+8	$D+\tau+t_f/2$
STO TEMP+8	$(D+\tau+t_f/2)^2$
CLA TEMP+1	t_f
FDP CONST+5	12
FMP TEMP+1	t_f
FAD TEMP+8	$(D+\tau+t_f/2)^2$
STO TEMP+8	$t_f^2/12+(D+\tau+t_f/2)^2$
LDQ TEMP+4	$(W-t_w)t_f$
FMP TEMP+8	$t_f^2/12+(D+\tau+t_f/2)^2$
FAD TEMP+7	$I_0=(\lambda-t_w)t_f^3/3+(D+\tau+t_f)^3\frac{t_w}{3}+$
STO TEMP+7	$+(W-t_w)t_f\left[t_f^2/12+(D+\tau+\frac{t_f}{2})^2\right]$
CLA TEMP+6	Q
FDP TEMP+5	A
STQ TEMP+8	$c=Q/A$
CLA TEMP+2	D
FAD TEMP+1	t_f
FAD LOC+7,1	τ

FSB TEMP+8	c
STO TEMP+9	c'
LDQ TEMP+8	c
FMP TEMP+8	c
STO TEMP+10	c^2
LDQ TEMP+10	c^2
FMP TEMP+5	A
SSM	
FAD TEMP+7	I_0
STO TEMP+7	$I = I_0 - Ac^2$
REM CALCULATION OF SECTION MODULI	
FDP TEMP+8	c
STQ TEMP+10	I/c
CLA TEMP+7	I'
FDP TEMP+9	c'
STQ TEMP+11	I/c'
REM STRESS SCHEDULES	
CLA LOC+22,1	P (POSITIVE IN COMPRESSION)
FDP TEMP+5	A
STQ TEMP+12	$\sigma_A^- = P/A$
CLA LOC+24,1	M
FDP TEMP+11	I/c'
STQ TEMP+13	$\sigma_B^- = Mc'/I$
CLA TEMP+13	σ_B^-
FAD TEMP+12	σ_A^-
CAS INPUT+17	COMPARE $\sigma_A^- + \sigma_B^-$ WITH σ_{YP}^-
NOP	
TRA INSEK	IF $\sigma_A^- + \sigma_B^- \geq \sigma_{YP}^-$

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	CHS		
	CAS	INPUT+16	COMPARE $-(\sigma_B^- + \sigma_A^-)$ WITH σ_{YP}^+
	NOP		
	TRA	INSEK	IF $-(\sigma_B^- + \sigma_A^-) \geq \sigma_{YP}^+$
	CLA	LOC+24,1	M
	FDP	TEMP+10	I/c
	STQ	TEMP+13	$\sigma_B = Mc/I$
	CLA	TEMP+13	σ_B
	FSB	TEMP+12	σ_A^-
	CAS	INPUT+16	COMPARE $\sigma_B - \sigma_A^-$ WITH σ_{YP}^+
	NOP		
	TRA	INSEK	IF $\sigma_B - \sigma_A^- \geq \sigma_{YP}^+$
	CHS		
	CAS	INPUT+17	COMPARE $\sigma_A^- - \sigma_B$ WITH σ_{YP}^-
	NOP		
	TRA	INSEK	IF $\sigma_A^- - \sigma_B \geq \sigma_{YP}^-$
	TRA	INSEL	IF STRESS SCHEDULES ARE SATISFACTORY
	REM	RESIZING WEB FRAME	
INSEK	CLA	TEMP+2	D
	FAD	TEMP+1	t_f
	STO	TEMP+2	$D = D + t_f$
	CAS	TEMP+19	COMPARE D WITH 60 t_w
	NOP		
	TRA	*+2	IF $D \geq 60\, t_w$ INCREASE W
	TRA	INSEJ	
	CLA	TEMP+3	W
	FAD	TEMP+1	t_f
	STO	TEMP+3	$W = W + t_f$

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GENERAL EQUILIBRIUM EQUATIONS

ASSUME 2 SYMMETRICALLY SPACED STANCHIONS PROVIDING A REDUNDANT FORCE R_0 (POSITIVE IN COMPRESSION)

$$P_K = P_0 \cos\theta_K + Q_0 \sin\theta_K - \cos\theta_K \sum_{i=0}^{i=K} h_i + \sin\theta_K \sum_{i=0}^{i=K} v_i - \underbrace{R_0 \sin\theta_K}_{Y_K > Y_R}$$

$$= P_0 \cos\theta_K + Q_0 \sin\theta_K + P_{EX} - R_0 \sin\theta_K$$

WHERE $P_{ex} = -\cos\theta_K \sum_{i=0}^{i=K} h_i + \sin\theta_K \sum_{i=0}^{i=K} v_i$

$$Q_K = -P_0 \sin\theta_K + Q_0 \cos\theta_K + \sin\theta_K \sum_{i=0}^{i=K} h_i + \cos\theta_K \sum_{i=0}^{i=K} v_i + \underbrace{R_0 \cos\theta_K}_{Y_K > Y_R}$$

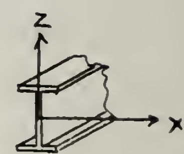
$$= -P_0 \sin\theta_K + Q_0 \cos\theta_K + Q_{EX} + R_0 \cos\theta_K$$

WHERE $Q_{EX} = \sin\theta_K \sum_{i=0}^{i=K} h_i + \cos\theta_K \sum_{i=0}^{i=K} v_i$

$$M_K = M_0 - P_0 z_K + Q_0 Y_K + \sum_{i=0}^{i=K} h_i (z_K - z_i) + \sum_{i=0}^{i=K} v_i (Y_K - Y_i) - \underbrace{R_0 (Y_K - Y_r)}_{Y_K > Y_R}$$

$$= M_0 - P_0 z_K + Q_0 Y_K + M_{EX} - R_0 (Y_K - Y_2)$$

WHERE $M_{EX} = \sum_{i=0}^{i=K} h_i (z_K - z_i) + \sum_{i=0}^{i=K} v_i (Y_K - Y_i)$



ASSUME STANCHION TO BE PIN CONNECTED

INTERNAL ENERGY STORED IN WEB UNDER LOAD:

$$U = \frac{1}{2E} \oint \frac{P_K^2}{A_K} dl + \frac{1}{2G} \oint \frac{\mu Q_K^2}{A_K} dl + \frac{1}{2E} \int \frac{M_K^2}{I_K} dl + \frac{R_0^2 L}{2AE}$$

$$\mu = \frac{\iint \tau^2 \, dz\, dx}{\left[\iint \tau \, dz\, dx\right]^2}$$

$$\frac{dU}{dP_0} = \frac{1}{E} \oint \frac{P_K}{A_K} \frac{dP_K}{dP_0} dl + \frac{1}{G} \oint \frac{\mu Q}{A_K} \frac{dQ}{dP_0} dl + \frac{1}{E} \oint \frac{M_K}{I_K} \frac{dM_K}{dP_0} dl + \frac{R_0 L}{AE} \frac{dR_0}{dP_0} = 0$$

$$\tau = \frac{VQ}{tI} = \frac{V}{tI} \iint z \, dz\, dx$$

$$\frac{dU}{dQ_0} = \frac{1}{E} \oint \frac{P_K}{A_K} \frac{dP_K}{dQ_0} dl + \frac{1}{G} \oint \frac{\mu Q_K}{A_K} \frac{dQ_K}{dQ_0} dl + \frac{1}{E} \oint \frac{M_K}{I_K} \frac{dM_K}{dQ_0} dl + \frac{R_0 L}{AE} \frac{dR_0}{dQ_0} = 0$$

$$\frac{dU}{dM_0} = \frac{1}{E} \oint \frac{P_K}{A_K} \frac{dP_K}{dM_0} dl + \frac{1}{G} \oint \frac{\mu Q_K}{A_K} \frac{dQ_K}{dM_0} dl + \frac{1}{E} \oint \frac{M_K}{I_K} \frac{dM_K}{dM_0} dl + \frac{R_0 L}{AE} \frac{dR_0}{dM_0} = 0$$

$$\frac{dP_K}{dP_0} = \cos\theta \qquad \frac{dQ_K}{dP_0} = -\sin\theta \qquad \frac{dM_K}{dP_0} = -z_K \qquad \frac{dR_0}{dP_0} = \cot\theta$$

$$\frac{dP_K}{dQ_0} = \sin\theta \qquad \frac{dQ_K}{dQ_0} = \cos\theta \qquad \frac{dM_K}{dQ_0} = -Y_K \qquad \frac{dR_0}{dQ_0} = 1$$

$$\frac{dP_K}{dM_0} = 0 \qquad \frac{dQ_K}{dM_0} = 0 \qquad \frac{dM_K}{dM_0} = 1 \qquad \frac{dR_0}{dM_0} = \frac{1}{(Y_K - Y_R)}$$

$Y \le \frac{B}{2} - R$: $dl = dy$

$\frac{B}{2} - R \le Y \le \frac{B}{2}$: $dl = R\,d\theta$

$R < z < D$: $dl = dz$

$z = D$: $dl = dY$

```
      CAS TEMP+18                      COMPARE W WITH 30 tw
      NOP
      TRA *+6                          IF W ≥ 30 tw INCREASE tw
      CLA TEMP+3                       W
      FDP CONST+2                      2
      STQ TEMP+2                       D ≥ W/2
      LXD NIX,1                        RESET INDEX 1
      TRA INSEJ                        W = CONST OVER WEB FRAME
      LXD NIX,1                        RESET INDEX 1
INDDD TXI INSEI,2                      tw = CONST OVER WEB FRAME
      REM STORE INTERMEDIATE DATA
INSEL CLA TEMP                         tw
      STO LOC+6,1                      tw
      CLA TEMP+1                       τf
      STO LOC+7,1                      τf
      CLA TEMP+2                       D
      STO LOC+8,1                      D
      CLA TEMP+3                       W
      STO LOC+9,1                      W
      CLA TEMP+5                       A
      STO LOC+10,1                     A
      CLA TEMP+6                       Q
      STO LOC+11,1                     Q
      CLA TEMP+7                       I
      STO LOC+12,1                     I
      CLA TEMP+8                       C
      STO LOC+13,1                     C
      CLA TEMP+9                       C'
      STO LOC+14,1                     C'
```

THE FOLLOWING ASSUMPTIONS WERE MADE FOR THIS PROGRAM

1. NO STANCHIONS: $R_0 = 0$
2. SYMMETRICAL LOADING ABOUT CENTERLINE: $Q_0 = 0$
3. SHEAR STRESSES AND STRAINS IGNORED $Q \approx 0$

THE EQUILIBRIUM EQUATIONS ON THE PRECEDING PAGE BECOME:

$$P_K = P_0 \cos\theta_K + P_{EX} \qquad \frac{dP_K}{dP_0} = \cos\theta_K \qquad \frac{dP_K}{dM_0} = 0$$

$$M_K = M_0 - P_0 Z_K + M_{EX} \qquad \frac{dM}{dP_0} = -Z_K \qquad \frac{dM}{dM_0} = 1$$

INTERNAL ENERGY EQUATIONS BECOME:

$$\frac{dU}{dP_0} = \frac{1}{E}\oint \frac{P_K}{A_K}\frac{dP_K}{dP_0}dl + \frac{1}{E}\oint \frac{M_K}{I_K}\frac{dM_K}{dP_0}dl = 0$$

$$\oint\left(\frac{P_0\cos\theta_K + P_{EX}}{A_K}\right)(\cos\theta_K)dl - \oint\left(\frac{M_0 - P_0 Z_K + M_{EX}}{I_K}\right)(Z_K)dl = 0$$

$$P_0\oint\left(\frac{\cos^2\theta_K}{A_K} + \frac{Z_K^2}{I_K}\right)dl - M_0\oint\left(\frac{Z_K}{I_K}\right)dl + \oint\left(\frac{P_{EX}\cos\theta_K}{A_K} - \frac{M_{EX}Z_K}{I_K}\right)dl = 0$$

$$\frac{dU}{dM_0} = \frac{1}{E}\oint \frac{P_K}{A_K}\frac{dP_K}{dP_0}dl + \frac{1}{E}\oint \frac{M_K}{I_K}\frac{dM_K}{dP_0}dl = 0$$

$$\oint\left(\frac{M_0 - P_0 Z_K + M_{EX}}{I_K}\right)dl = 0$$

$$-P_0\oint\left(\frac{Z_K}{I_K}\right)dl + M_0\int\left(\frac{1}{I_K}\right)dl + \int\left(\frac{M_{EX}}{I_K}\right)dl = 0$$

THE INTEGRATIONS ARE APPROXIMATED BY SUMMATIONS:

$dl = b$

$$P_0\sum_{K=0}^{K=n}\left(\frac{\cos^2\theta_K}{A_K} + \frac{Z_K^2}{I_K}\right) + M_0\sum_{K=0}^{K=n}-\left(\frac{Z_K}{I_K}\right) + \sum_{K=0}^{K=n}\left(\frac{P_{EX}\cos\theta_K}{A_K} - \frac{M_{EX}Z_K}{I_K}\right) = 0$$

$$P_0\sum_{K=0}^{K=n}-\left(\frac{Z_K}{I_K}\right) + M_0\sum_{K=0}^{K=n}\left(\frac{1}{I_K}\right) + \sum_{K=0}^{K=n}\left(\frac{M_{EX}}{I_K}\right) = 0$$

FROM WHICH:

$$P_0 = -\frac{\left[\sum_{K=0}^{K=n}\left(\frac{Z_K}{I_K}\right)\right]\left[\sum_{K=0}^{K=n}\left(\frac{M_{EX}}{I_K}\right)\right] + \left[\sum_{K=0}^{K=n}\left(\frac{P_{EX}\cos\theta_K}{A_K} - \frac{M_{EX}Z_K}{I_K}\right)\right]\left[\sum_{K=0}^{K=n}\left(\frac{1}{I_K}\right)\right]}{\left[\sum_{K=0}^{K=n}\left(\frac{\cos^2\theta_K}{A_K} + \frac{Z_K^2}{I_K}\right)\right]\left[\sum_{K=0}^{K=n}\left(\frac{1}{I_K}\right)\right] - \left[\sum_{K=0}^{K=n}\left(\frac{Z_K}{I_K}\right)\right]^2}$$

$$M_0 = \frac{\left[\sum_{K=0}^{K=n}\left(\frac{Z_K}{I_K}\right)\right]P_0 - \left[\sum_{K=0}^{K=n}\left(\frac{M_{EX}}{I_K}\right)\right]}{\left[\sum_{K=0}^{K=n}\left(\frac{1}{I_K}\right)\right]}$$

```
                                   140
      CLA  TEMP+3                                  W
      FDP  CONST+2                                 2
      STQ  TEMP+2                                  D ≥ W/2
INDEJ TXI  *+1,1
      CLA  LOC+1,1                                 Z
      TMI  *+2                                     IF Z=-1, LEAVE LOOP
      TRA  INSEJ
      LXD  NIX,3                                   RESET INDICES 1 AND 2
      REM  CALC OF REDUNDANT FORCES
      STZ  TEMP                                    SET TO ZERO
      STZ  TEMP+1                                  SET TO ZERO
      STZ  TEMP+2                                  SET TO ZERO
      STZ  TEMP+3                                  SET TO ZERO
INSEM CLA  LOC+1,1                                 Z
      TMI  INDEK+1                                 IF Z=-1, LEAVE LOOP
      CLA  LOC+19,1                                COS Θ
      FDP  LOC+10,1                                A
      FMP  LOC+19,1                                COS Θ
      FAD  TEMP                                    Σ COS²Θ/A
      STO  TEMP                                    Σ COS²Θ/A
      CLA  LOC+1,1                                 Z
      FDP  LOC+12,1                                I
      STQ  TEMP+6                                  Z/I
      FMP  LOC+1,1                                 Z
      FAD  TEMP                                    Σ COS²Θ/A
      STO  TEMP                                    Σ[Z²/I + COS²Θ/A]
      CLA  TEMP+6                                  Z/I
      FAD  TEMP+1                                  Σ Z/I
      STO  TEMP+1                                  Σ Z/I
                             149  149
```

148 148

	CLA	LOC+3,1	P_{ex}
	FDP	LOC+10,1	A
	FMP	LOC+19,1	$\cos\theta$
	FAD	TEMP+2	$\Sigma \frac{P_{ex}\cos\theta}{A}$
	STO	TEMP+2	$\Sigma \frac{P_{ex}\cos\theta}{A}$
	CLA	LOC+5,1	M_{ex}
	FDP	LOC+12,1	I
	FMP	LOC+1,1	z
	CHS		
	FAD	TEMP+2	$\Sigma \frac{P_{ex}\cos\theta}{A}$
	STO	TEMP+2	$\Sigma \left[\frac{P_{ex}\cos\theta}{A} - \frac{M_{ex}z}{I}\right]$
	CLA	CONST+1	1.0
	FDP	LOC+12,1	I
	STQ	TEMP+6	$1/I$
	CLA	TEMP+6	$1/I$
	FAD	TEMP+3	$\Sigma\, 1/I$
	STO	TEMP+3	$\Sigma\, 1/I$
	CLA	LOC+5,1	M_{ex}
	FDP	LOC+12,1	I
	STQ	TEMP+6	M_{ex}/I
	CLA	TEMP+6	M_{ex}/I
	FAD	TEMP+4	$\Sigma\, M_{ex}/I$
	STO	TEMP+4	$\Sigma\, M_{ex}/I$
INDEK	TXI	INSEM,1	
	CLA	TEMP+1	$\Sigma\, z/I$
	CHS		
	STO	TEMP+1	$-\Sigma\, z/I$
	CLA	TEMP+4	$\Sigma \frac{M_{ex}}{I}$

FDP TEMP+3	$\Sigma\ 1/I$
FMP TEMP+1	$-\Sigma\ 2/I$
FSB TEMP+2	$\Sigma\left[\frac{P_{ex}\cos\theta}{A} - \frac{M_{ex}{}^{2}}{I}\right]$
STO TEMP+6	$\left(\Sigma \frac{M_{ex}}{I}\right)\left(-\Sigma \frac{2}{I}\right)\left(\Sigma\ 1/I\right)^{-1} - \Sigma\left[\frac{P_{ex}\cos\theta}{A} - \frac{M_{ex}{}^{2}}{I}\right]$
CLA TEMP+1	$-\Sigma\ 2/I$
FDP TEMP+3	$\Sigma\ 1/I$
FMP TEMP+1	$-\Sigma\ 2/I$
CHS	
FAD TEMP	$\Sigma \cos^2\theta/A$
STO TEMP+7	$\Sigma \cos^2\theta/A - (-\Sigma\ 2/I)^2(\Sigma\ 1/I)^{-1}$
CLA TEMP+6	$\left(\Sigma \frac{M_{ex}}{I}\right)\left(-\Sigma \frac{2}{I}\right)\left(\Sigma \frac{1}{I}\right)^{-1} - \Sigma\left[\frac{P_{ex}\cos\theta}{A} - \frac{M_{ex}{}^{2}}{I}\right]$
FDP TEMP+7	$\Sigma \cos^2\theta/A - (-\Sigma\ 2/I)^2(\Sigma\ 1/I)^{-1}$
STQ REMEM+11	P_0
CLA REMEM+11	P_0
FDP TEMP+3	$\Sigma\ 1/I$
FMP TEMP+1	$-\Sigma\ 2/I$
STO TEMP+6	$P_0(-\Sigma\ 2/I)(\Sigma\ 1/I)^{-1}$
CLA TEMP+4	$\Sigma\ M_{ex}/I$
FDP TEMP+3	$\Sigma\ 1/I$
STQ TEMP+7	$(\Sigma\ M_{ex}/I)(\Sigma\ 1/I)^{-1}$
CLA TEMP+7	$(\Sigma\ M_{ex}/I)(\Sigma\ 1/I)^{-1}$
FAD TEMP+6	$P_0(-\Sigma\ 2/I)(\Sigma\ 1/I)^{-1}$
CHS	
STO REMEM+12	$M_0 = (\Sigma\ M_{ex}/I)(\Sigma\ 1/I)^{-1} + P_0(-\Sigma\ 2/I)(\Sigma \frac{1}{I})^{-1}$
TSX R,4	Print out P_0, M_0
PZE REMEM+11,0,REMEM+12	
REM ACCURACY TEST FOR REDUNDANT FORCES	
CLA REMEM+11	P_0 (COMPUTED)
FSB REMEM+13	P_0 (PREVIOUS ESTIMATE)
FDP REMEM+11	P_0 (COMPUTED)

```
                    138
     STQ TEMP                       ΔP0
     CLA TEMP                       ΔP0
     SSP
     CAS INPUT+11                   COMPARE ΔP0 WITH ΔI
     TRA INSEN                      IF ΔP0 > ΔI
     NOP
     CLA REMEM+12                   M0 (COMPUTED)
     FSB REMEM+14                   M0 (PREVIOUS ESTIMATE)
     FDP REMEM+12                   M0 (COMPUTED)
     STQ TEMP                       ΔM0
     CLA TEMP                       ΔM0
     SSP
     CAS INPUT+11                   COMPARE ΔM0 WITH ΔI
     TRA INSEN                      IF ΔM0 > ΔI
     NOP
     TRA EXIT                       IF ΔM0 ≤ ΔI
     REM ALTERATION OF ESTIMATED REDUNDANT FORCES
INSEN CLA REMEM+11                  P0 (COMPUTED)
     FAD REMEM+13                   P0 (PREVIOUS ESTIMATE)
     FDP CONST+2                    2
     STQ REMEM+13                   P0 (NEW ESTIMATE)
     CLA REMEM+12                   M0 (COMPUTED)
     FAD REMEM+14                   M0 (PREVIOUS ESTIMATE)
     FDP CONST+2                    2
     STQ REMEM+14                   M0 (NEW ESTIMATE)
     LXD NIX,1                      RESET INDEX 1
     REM INSERT NEW EST OF REDUNDANT FORCE AND MOMENT
INSEO CLA LOC+1,1                   Z
     TMI INDEI+5                    IF Z=-1, LEAVE LOOP
                    152    152
```

```
      LDQ REMEM+13                    Po
      FMP LOC+19,1                    cos θ
      FAD LOC+3,1                     Pex
      STO LOC+22,1                    P= Pex + Po cos θ
      LDQ REMEM+13                    Po
      FMP LOC+1,1                     z
      CHS
      FAD REMEM+14                    Mo
      FAD LOC+5,1                     Mex
      STO LOC+24,1                    M = Mex + Mo - Pex z
INDEL TXI INSEO,1
EXIT  LXD NIX,1                       RESET INDEX 1
      REM PRINT OUT ANSWERS
      TSX R,4                         PRINT OUT Po, Mo
      PZE REMEM+11,0,REMEM+12
INSEP CLA LOC+1,1                     z
      TMI END                         IF z=-1, LEAVE LOOP
      CAL CRANK
      ACL FIVE
      SLW FIVE
      CAL CRANK
      ACL SIX
      SLW SIX
      TSX N,4                         PRINT OUT C, Z, Y
FIVE  PZE LOC-50,0,LOC-48
      TSX S,4                         PRINT OUT Tw, Tf, D, W
SIX   PZE LOC-44,0,LOC-41
INDEM TXI INSEP,1
END   HLT
```

```
L      TRA BLOCK
       BCD 76H AREA=E15.8,6H    N=F6.1,6H    A=F6.1
M      TRA BLOCK
       BCD 812H INERTIA PL=E15.8,16H    INERTIA MIN=E15.8
N      TRA BLOCK
       BCD 810H LOCATION=F6.1,6H    Z=F6.1,6H    Y=F6.1
O      TRA BLOCK
       BCD 627H LENGTH/RADIUS OF GYRATION=F6.1
P      TRA BLOCK
       BCD 918H LOCATION=F6.1,4H  Z=F6.1,4H  Y=F6.1,5H  WT=F6.1
Q      TRA BLOCK
       BCD 918H NEUTRAL AXIS SAG=F6.1,19H  NEUTRAL AXIS HOG=F6.1
R      TRA BLOCK
       BCD 67H    PO=E15.8,7H    MO=E15.8
S      TRA BLOCK
       BCD 95H  TW=F6.1,5H  TF=F6.1,4H  D=F6.1,4H  W=F6.1
INPUT BSS 30
LOAD   BSS 100
ASIDE BSS 15
REMEM BSS 15
LOC    BSS 5000
CONST DEC -1.0,1.0,2.0,0.29289,-0.4292
       DEC 12.0,40000.,1.70,7.7855,-0.04
       DEC 0.29767,-0.02171546,1.5708,0.8660,0.50
       DEC 10414.,0.0127,30.,18.,324.0
       DEC 54.,9.6,-1.6,-0.88,16970.6,20.,1.5
       DEC 0.90,1.10,2240.0,144.0,5.0,0.0,0.0,0.0,0.0,0.0
TEMP   BSS 40
```

```
NIX   PZE
CRANK PZE 50,0,50
HANDL PZE 0,0,24
      PZE 0,0,49
      PZE 0,0,9
      PZE 0,0,2
00008 TRA INSDF                          ESCAPE FROM (AC) UNDERFLOW
INSDF SXD TEMP+17,1
      LXD 0,1
      TNX INSDG,1,4
      CAL 0
      HTR
INSDG CAL 0
      STA INSDH
      PXD 0,0
      LXD TEMP+17,1
INSDH TRA 0
      END START
      CST M885-721-PROGRAM
      REM INPUT INFORMATION FOR PROGRAM M885
      SAP M885-721-INPUT
      LST OFF
      ORG INPUT
      DEC   .          (FT)  DEPTH
      DEC   .          (FT)  BEAM
      DEC              (FT)  BILGE RADIUS
      DEC   .          (FT)  FULL LOAD DRAFT
      DEC   .          (FT)  WAVE CREST HEIGHT ABOVE KEEL
```

```
DEC   .         (IN)       INITIAL FRAME SPACING
DEC   .         (IN)       INCREMENT OF FRAME SPACING
DEC   .         (IN)       FINAL FRAME SPACING
DEC   .                    INITIAL NUMBER OF LONGITUDINALS
DEC   .                    INCREMENT OF NUMBER OF LONGITUDINALS
DEC   .                    FINAL NUMBER OF LONGITUDINALS
DEC   .         (O/O)      ACCURACY CRITERION FOR MOM.OF INERTIA
DEC      .      (FT-TONS)  BENDING MOMENT SAGGING
DEC      .      (FT-TONS)  BENDING MOMENT HOGGING
DEC   .         (FT)       MINIMUM HYDROSTATIC HEAD
DEC      .      (PSI)      ULTIMATE STRENGTH
DEC      .      (PSI)      YIELD STRENGTH IN TENSION
DEC      .      (PSI)      YIELD STRENGTH IN COMPRESSION
DEC         .   (PSI)      YOUNGS MODULUS
DEC     .       (PSI)      SECONDARY BENDING STRESS AT PLATE
END 0

PMD M885-721-PROGRAM
PMR LOC,LOC+1000,FLO,FPR
CLR
PAK
RIP M885-721-DATA-DAVIS
RIP M885-721-INPUT
RIP M885-721-PROGRAM
BGN M885-721-PROGRAM
XPM M885-721-PROGRAM
TER M885-721-PROGRAM
```

Index of Addresses And Their Contents

CONST	0	-1.0	SCANT	0	BEAM DESIGNATION	PLATE	0	lb/ft^2
"	1	1.0	"	1	" "	"	1	t
"	2	2.0	"	2	" "	"	2	t^2
"	3	0.29289	"	3	A_s			
"	4	-0.4292	"	4	c'_s			
"	5	12.0	"	5	I_s			
"	6	40000.0	"	6	I_{syy}			
"	7	1.70	"	7	blank			
"	8	7.7855	"	8	blank			
"	9	-0.04	"	9	d			
"	10	0.29767						
"	11	-0.02171546						
"	12	1.5708	INPUT	0	D			
"	13	0.8660	"	1	B			
"	14	0.50	"	2	R			
"	15	10414.0	"	3	F			
"	16	0.0127	"	4	W			
"	17	30.0	"	5	a_o, a			
"	18	18.0	"	6	Δa			
"	19	324.0	"	7	a_f			
"	20	54.0	"	8	n_o			
"	21	9.6	"	9	Δn			
"	22	-1.6	"	10	n_f			
"	23	-0.88	"	11	ΔI			
"	24	16970	"	12	M_1^+			
"	25	20.0	"	13	M_1^-			
"	26	1.5	"	14	H_o			
"	27	0.90	"	15	σ_{ULT}			
"	28	1.10	"	16	σ_{yp}^+			
"	29	2240.0	"	17	σ_{yp}^-			
"	30	144.0	"	18	E			
"	31	5.0	"	19	σ_2			

PAGE:	114	116	118	120	122	124	126	128	130	132	134	136	138	140	142	144	146	148
TEMP		θ			λt		$\Sigma A_1(SAG)$	ΔI	$\Sigma A \Sigma A_2^+$			t_w			t_w	$\Sigma \frac{\cos^2\theta}{A} + \Sigma z^2/I$		
" +1		$\Delta\theta$			$\lambda t^3/12$		$\Sigma A_1(HOG)$		$\Sigma A_2^+ z$			t_f			t_f	$\Sigma\, z/I$		
" +2		$\sin\theta$			$\lambda^- t$		$\Sigma A_2(SAG)$	I_1^+	$\Sigma A_2^+ z^2 I$				D	D	$\Sigma F' ex\cos\theta/A - Mex^2/I$			
" +3		$\cos\theta$			$\lambda^- t^3/12$		$\Sigma A_2(HOG)$	I_1^-	$\Sigma A(z_c - z)$				W	W		$\Sigma 1/I$		
" +4					A_2					$\Sigma H\sin\theta$		$(\lambda - t_w)$				$\Sigma Mex/I$		
" +5					A_2^-					$\Sigma[H\cos\theta - (c+w)]$			A					
" +6					$t/2$								Q					
" +7					$(\lambda^-)^3 t/12$								I_0	I				
" +8					I_{2yy}								c					
" +9					I_{2yy}^-								c'					
" +10					c_2'								I/c					
" +11						$c_2'^-$												
" +12													σ_A^-					
" +13													σ_B^- σ_B					
" +14						I_2												
" +15						I_2^-												
" +16						K												
" +17																		
" +18	+1.0											$30t_w$						
" +19												$60t_w$						
" +20					$d - c_3' + t/2$													

ASIDE	n_0
" +1	b_0
" +2	b_0
" +3	b^2
" +4	$b^3/12$
" +5	$B/2$
" +6	
" +7	$\frac{1}{2}(F - R)$
" +8	$\frac{1}{2}b_0, \frac{1}{2}b$
" +9	$B/2 - R$
" +10	λ^-/t
" +11	λ

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LOC			c																
"	+1		z																
"	+2		Y																
"	+3						BEAM DESIGNATION						P_{EX}						
"	+4						BEAM DESIGNATION						Q_{EX}						
"	+5						BEAM DESIGNATION					M_{EX}							
"	+6				a/k (max)											t_w			
"	+7				t											t_f			
"	+8			σ_1^+												D			
"	+9			σ_1^-												W			
"	+10				M_2											A			
"	+11						A_2^+									Q			
"	+12				I_2/c (min)						$\Sigma H\sin\theta + S\cos\theta$					I			
"	+13				I_2/c' (min)						$\Sigma[H\cos\theta - (c+\omega) - S\sin\theta]$					c			
"	+14				λ^-											c'			
"	+15			H(max)							$H\sin\theta$, $H\sin\theta + S\cos\theta$								
"	+16			H_w							$H\cos\theta - (c+\omega) - S\sin\theta$								
"	+17		θ																
"	+18										$\sin\theta$								
"	+19										$\cos\theta$								
"	+20						A_2^-			$Q = \Sigma A(z_c - z)$		$S\sin\theta$							
"	+21						I_2					$S\cos\theta$							
"	+22						I_2^-						P					P	
"	+23						I_{2YY}						Q					Q	
"	+24						I_{2YY}^-					M						M	
"	+25		c																
"	+26		z																
"	+27		Y																
"	+28				PLATE DESIGNATION														
"	+29				t														
"	+30				t^2														
"	+31																		
"	+32																		
"	+33			σ_1^+															
"	+34			σ_1^-															

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Location	Contents
LOC + 35	σ_3
" + 36	
" + 37	
" + 38	
" + 39	
" + 40	H(MAX)
" + 41	H_w
" + 42	θ
" + 43	
" + 44	
" + 45	
" + 46	
" + 47	
" + 48	
" + 49	
159	
REMEM	I_1^+ (EST) — I_1^+ (NEW EST)
" + 1	I_1^- (EST) — I_1^- (NEW EST)
" + 2	z_c^+ (EST) — z_c^+ (COMPUTED) z_c^+ (NEW EST)
" + 3	z_c^- (EST) — z_c^- (COMPUTED) z_c^- (NEW EST)
" + 4	Vb/I
" + 5	A_1(min)
" + 6	z_c^+ (EST)
" + 7	z_c^- (EST)
" + 8	
" + 9	
" + 10	$(M/I)_1^+$
" + 11	$(M/I)_1^-$ — P_o (COMP.)
" + 12	A_1 — M_o (COMP.)
" + 13	n — P_o (EST)
" + 14	a — M_o (EST)

FLOW DIAGRAM FOR CALCULATION OF WEB FRAME DIMENSIONS

Note: assume that all scantlings and plating have been selected.

Compute area and first and second moments thereof

Location of neutral axis and moment of inertia

Compute Q, first moment of area for each location
is $z < 0$? ——— NO

Compute sinθ and cosθ for each location
is $z < 0$? ——— NO

Compute hydrostatic and internal load components for each location
is $z < 0$? ——— NO

Summation of external forces for each location
is $z < 0$? ——— NO

Calculate the shear force factor Vb/I

Compute shear forces for each location
is $z < 0$? ——— NO

Compute moments caused by external forces including shear forces
is $z < 0$? ——— NO

Compute axial and shear forces in the frame due to external loads and shear forces for each location
is $z < 0$? ——— NO

Compute web dimensions

Compute area and moment of inertia of Web

Compute section moduli of web

Calculate stress schedules
are total stress less than yield
stress? — YES

Increase D (depth of web)
Is $D \geqslant 60t_w$? — NO

Increase W (flange width)
Is $W \geqslant 30t_w$? — NO → set $D = \frac{1}{2}W$, reset LOC

Increase t_w → reset LOC

Store web dimensions
is $z < 0$? — NO — SET $D = \frac{1}{2}W$

Calculate redundant forces and moments

Accuracy test for redundant forces and
moments. Is the accuracy criterion
satisfied? — NO — alter and insert
redundant forces
and moments

Print out answers and
end program.

APPENDIX E

BIBLIOGRAPHY

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